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Hydrology of the New Oxford Formation in Lancaster County, Pennsylvania

Herbert E. Johnston

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DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

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Hydrology of the New Oxford Formation in Lancaster County, Pennsylvania

by Herbert E. Johnston
U. S. Geological Survey

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By

Herbert E. Johnston

ABSTRACT

The New Oxford Formation, of Late Triassic age, extends across the northern part of Lancaster County. It consists of a complexity interbedded sequence of stream-deposited sedimentary rocks consisting of conglomerate, sandstone, siltstone, and shale. The sandstone is commonly subarkosic (10 to 25 percent feldspar content) and is the most abundant rock type. The beds have a steep homoclinal dip to the north or northwest that ranges from 25° to 60°.

In the consolidated bedrock of the New Oxford Formation, water occurs chiefly in joints and in intergranular openings in weathered rock bordering the joints. Sandstones and conglomerates are the principal water-yielding rocks, and yielding zones generally occur in beds that have been more thoroughly fractured or weathered than others. Drilled wells obtain most of their water from thin lens-shaped zones that are oriented parallel to bedding planes and generally are of small areal extent. These zones commonly are only a few inches thick and are separated vertically by several feet or several tens of feet of rock that yields little or no water directly to the wells. In the mantle of loosely consolidated weathered material that overlies the bedrock, ground water occurs largely in intergranular openings.

Recharge to the ground-water reservoir comes from the approximately 40 inches of precipitation received by the area annually. Most recharge occurs during the nongrowing season (November to March) even though more than 50 percent of the total annual precipitation occurs during the growing season (April to October). Recharge from precipitation is greatly reduced during the growing season because a very large fraction of the precipitation is consumed by evapotranspiration.

The transmissibility of the northern half of the formation between the Susquehanna River and Denver is greater than that of the southern half, but the difference appears to be small. The median yield of 123 wells 300 feet or less in depth in the upper half is about 14 gpm (gallons per minute), and the median yield of 86 wells in the same depth range in the lower half is about 10 gpm. Several high yielding wells on or near faults in the eastern part of Lancaster County indicate that the transmissibility of the formation is high near these faults.

Depths of 377 drilled wells investigated range from 27 to 705 feet, but 80 percent of the wells are between 50 to 150 feet deep. The reported yields of 319 wells range from less than 1 to 330 gpm, and the median yield is 12 gpm. No well-defined relationship exists between yield and well depth. Some deep wells are highly yielding, others are failures; however, the highest yields generally are obtained from 8-inch or larger wells drilled to depths of more than 300 feet. Of 14 wells deeper than 300 feet, 7 yield more than 100 gpm, but of 146 wells between 100 and 300 feet deep, only 6 yield more than 100 gpm.

Specific capacities of wells in the New Oxford Formation are relatively low, indicating that the transmissibility of the formation also is rather low. Specific capacities of 27 wells pumped for 1 hour at discharges of 4 to 27 gpm range from 0.2 to 57.6 gpm (gallons per minute) per foot of drawdown, and the median value is 0.7 gpm per foot of drawdown. Specific capacities of 13 wells pumped for 7 to 72

hours at rates of 50 to 450 gpm range from 0.2 to 13.9, and the median value is 1.2. Most of the latter group of wells are large-diameter (8 to 10 inches) production wells more than 200 feet deep.

A considerable part of the drawdown (at moderate rates of discharge) in most 6-inch wells is believed to be caused by well loss (drawdown caused by resistance to the flow of water into and within the well to the pump intake). About one-quarter of the drawdown in a 6-inch test well, at a discharge of about 50 gpm, is attributed to well loss. A significant fraction of the drawdown in large-diameter wells is probably caused by well loss when these wells are pumped at high rates of discharge. The specific capacities of many wells might be improved substantially by increasing the effective diameter of the well either by drilling or by well-stimulation techniques such as surging.

Ground water from the New Oxford Formation is of the calcium-bicarbonate type and, with the exception of some water that may require treatment for hardness is generally satisfactory for most purposes. More than 80 percent of 349 wells sampled yielded water having a total disolved-solids content of less than 250 ppm (parts per million), and fewer than 1 percent yielded water containing more than 500 ppm. More than 60 percent of the wells and springs yield water that is soft (0 to 6 ppm as $CaCO_3$) to moderately hard (61 to 120 ppm) and fewer than 10 percent of them yield water that is very hard (more than 180 ppm).

Locally, the ground water is contaminated as a result of human activities. In most instances the source of contamination is within a few hundred feet of the well or spring affected. The contaminants include bacteria, nitrate, iron, manganese, juices from silos, gasoline, and fuel oil.

INTRODUCTION

PURPOSE OF THIS INVESTIGATION

The purpose of the ground-water investigation on which this report is based was to evaluate the New Oxford Formation in Lancaster County, as a source of ground water, and to evaluate also the factors that affect the performance of wells in the formation. The investigation was begun in September 1962 as a part of the continuing study of ground-water resources of Pennsylvania being made by the U.S. Geological Survey in cooperation with the Pennsylvania Topographic and Geologic Survey. This report, the second of two hydrologic studies of the New Oxford Formation, is concerned with the part of the formation that is east of the Susquehanna River. (See Fig. 1.)

Local variations in the transmissibility of the bedrock are common. Consequently, the yield of closely spaced wells that penetrate the same sequence of beds may differ considerably. Although there appear to be no marked areal differences in the transmissibility of the formation, a comparison of the yields of wells 300 feet deep or less in depth — in the area between the Susquehanna River and Denver — indicates that the transmissibility of the northern half of the formation is slightly greater than that of the southern half. The median yield of 123 wells in the northern half is about 14 gpm; the median yield of 86 wells in the south-

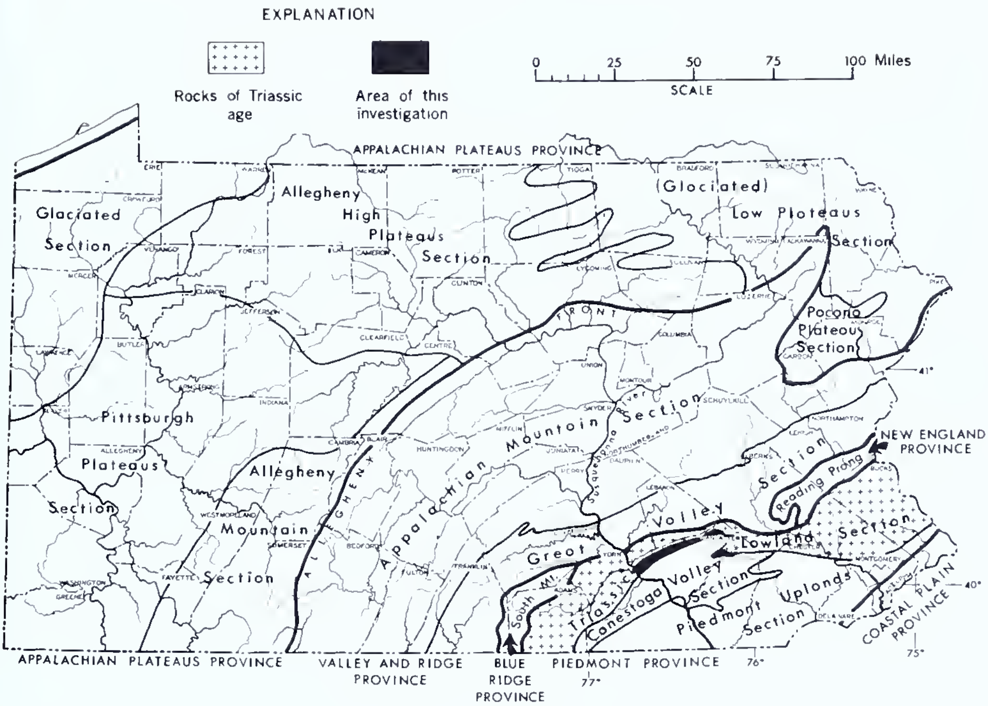


Figure 1. Map of Pennsylvania showing area of this investigation and area underlain by Triassic rocks.

ern half is about 10 gpm. Moreover, 10 of the wells in the upper half yield more than 50 gpm and 4 yield more than 100 gpm, whereas only 3 wells in the lower half yield more than 50 gpm and none yield as much as 100 gpm.

No clear cut relationship exists between the yield and the topographic position of a well, but valleys drained by perennially flowing streams are more favorable as sites for production wells than are ridges and slopes. A production well near a perennial stream may induce recharge from it and thereby experience smaller declines in yield during periods when recharge from precipitation is low. Fault zones also appear to be favorable sites for production wells. A few high-yielding wells have been drilled on or near faults in the eastern part of the area, indicating that the permeability of the rock is relatively high in the immediate vicinity of these structures.

Specific capacities of wells in the New Oxford Formation are generally low, indicating that the transmissibility of the formation as a whole is also rather low.

Specific capacities of 26 wells pumped for 1 hour at low rates of discharge (4 to 27 gpm) range from 0.2 to 57.6 gpm per foot of drawdown, and the median value is 0.7. Only 5 of these wells have specific capacities greater than 3.0. Specific capacities of 13 wells pumped for several

hours at discharges ranging from 50 to 450 gpm range from 0.2 to 13.9 and the median value is 1.2. The maximum specific capacity is 3.4, if data from 4 wells on or near faults are excluded. Because specific capacities of wells in the New Oxford Formation commonly decrease substantially as the time or rate of discharge increases, the data from the group of wells pumped for several hours are more indicative of specific capacities to be expected from production wells. The specific capacities of most wells drilled in the formation probably will not exceed 3.0 if determined from wells pumped at high rates of discharge for periods of several hours.

Ground water from the New Oxford Formation is of the calcium bicarbonate type and is generally of good chemical quality. Water from most wells and springs sampled has a dissolved-solids content of less than 250 ppm, and nearly two-thirds of the wells and springs sampled yield water that is soft to moderately hard (0 to 120 ppm as $CaCO_3$). The water from a few wells is very hard (more than 180 ppm).

The ground water is contaminated locally as a result of human activities. In most cases, however, the source of contamination is within a few hundred feet of the well or spring affected. Septic tank drain fields, cesspools, and barnyards are the most common sources of contaminants. In many instances, contamination may have resulted because the well was not cased deep enough or because the annular opening around the casing was inadequately sealed. The contaminants found by chemical analysis or reported by the owner include bacteria, nitrate, iron, manganese, juices from silos, gasoline, and fuel oil.

METHODS USED IN THIS INVESTIGATION

The data used in this investigation were obtained largely from an inventory of about 450 wells and springs. All public supply and industrial wells in the project area are included in the inventory. Most of the information was obtained from the owners or from drillers' files. The well and spring records are given in Table 4, and the locations of all wells and springs inventoried are shown on Plate 1.

Field measurements of specific conductance and hardness were made on water samples from about 350 wells and springs; pH was determined for 170 samples, and the temperature was recorded for 85 samples. These field determinations are listed in Table 4, and complete chemical analyses of water samples from 27 wells and 1 spring are given in Table 5.

Pumping-test data are available for 37 wells. Twenty-nine of these wells were pumped by the author for periods of 1 hour or more to determine their specific capacities. Two 6-inch test wells (Ln-88 and Ln-242) were drilled to obtain detailed information about the depth, thickness, spacing, and yielding capacity of individual water-bearing zones.

Test well Ln-88 was pumped at several rates of discharge for periods of 1 hour to determine the effect of the discharge rate on the specific capacity of the well.

Automatic water-level recorders were placed on selected wells to obtain continuous records of water-level fluctuations. Records were obtained from wells in which fluctuations resulted from natural causes and also from wells in which the fluctuations were caused partly by the pumping of nearby wells.

Detailed geologic observations were made at numerous bedrock outcrops and at well-drilling sites to obtain information about jointing, weathering, and other factors that might affect the occurrence and movement of ground water.

PREVIOUS INVESTIGATIONS

The geology of the Triassic rocks in Lancaster County is described in reports on the geology and mineral resources of the New Holland, Lancaster, and Middletown 15½-minute quadrangles by Jonas and Stose (1926, 1930) and Stose and Jonas (1933). The geologic map accompanying this report was compiled from the work of Dean B. McLaughlin. Most of the descriptive geologic data included in this report were obtained from two unpublished manuscripts by McLaughlin (1953, 1964) on file with the Pennsylvania Topographic and Geologic Survey, and from a report on the stratigraphy and origin of the Triassic rocks in Lebanon and Lancaster Counties by McLaughlin and Gerhard (1953).

Previous information concerning the water-bearing properties of the New Oxford Formation in Lancaster County is limited to a few brief statements in a reconnaissance report on the occurrence of ground water in southeastern Pennsylvania by Hall (1934). However, a recent study of the hydrology of the New Oxford Formation west of the Susquehanna River by Wood and Johnston (1964) includes much information pertinent to the formation in Lancaster County.

CLIMATE

The climate of Lancaster County is humid and is characterized by warm summers and mild winters. The average annual precipitation ranges from about 40 inches near the western end of the project area, at York Haven, in York County, to about 43 inches near the eastern end of the area, at Ephrata. The precipitation is distributed fairly evenly throughout the year (Fig. 2) but is generally greater during the 6-month period from May through October than during the 6-month period from November through April. At York Haven, for example, precipitation averages about 22 inches from May through October and about 18 inches from November through April. These periods correspond ap-

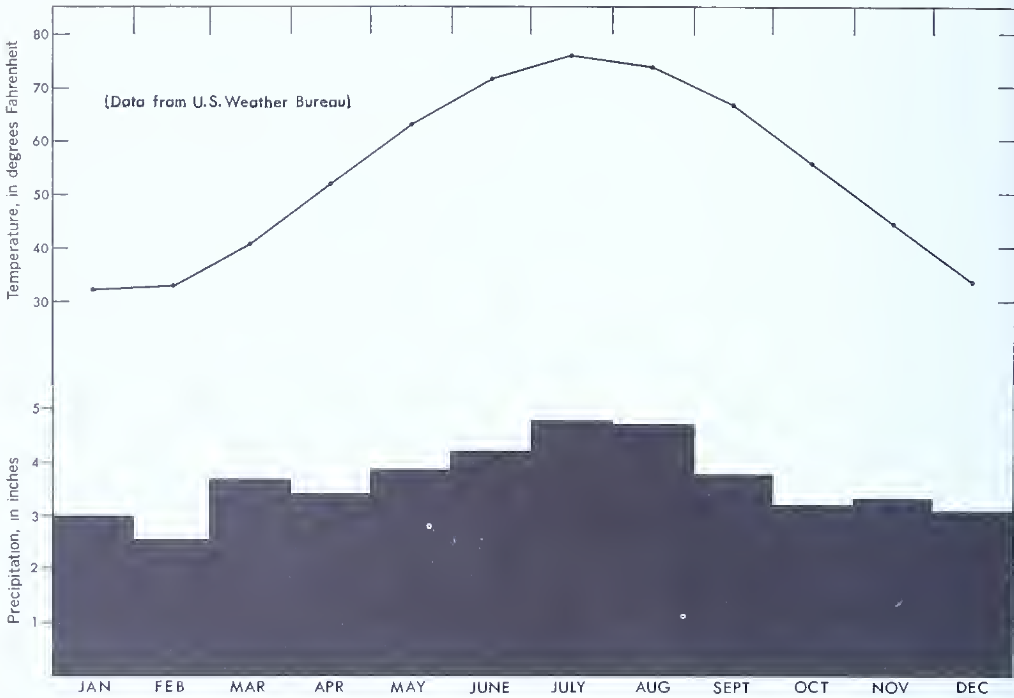


Figure 2. Graph showing average monthly precipitation and temperature at Ephrata, Pa., 1931-60. Data from U. S. Weather Bureau.

proximately with the growing and nongrowing seasons. Snowfall averages about 30 inches a year, and the fields are snow covered about one-third of the time during the winter months.

The average annual air temperature is about 53° F, and ranges from an average low of about 32° F in January to an average high of about 75° F in July. The average frost-free period in Lancaster County is 160 days. The average date of the last frost in the spring is April 30, and that of the first frost in autumn is October 7.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report consists of a county well number and a location number. The county numbers are listed in consecutive order in Table 4 and appear beside the well symbol on the well-location map (Pl. 1). The location number consists of a two-segment number that locates the well within a rectangular area bounded by 1-minute parallels of latitude and 1-minute meridians of longitude. The first segment of the location number refers to the latitude on the *south* side of the 1-minute quadrangle; the second segment refers to the longitude in the *east* side of this quadrangle. The first digit of the degree of latitude and the first digit of the degree of longitude are the same for all location numbers and, therefore, have been dropped for the sake of brevity. For example, well Ln-242, for which the location number is

009-633, is in the 1-minute quadrangle bounded on the south by latitude 40°09′ and on the east by longitude 76°33′. This example is illustrated in Figure 3.

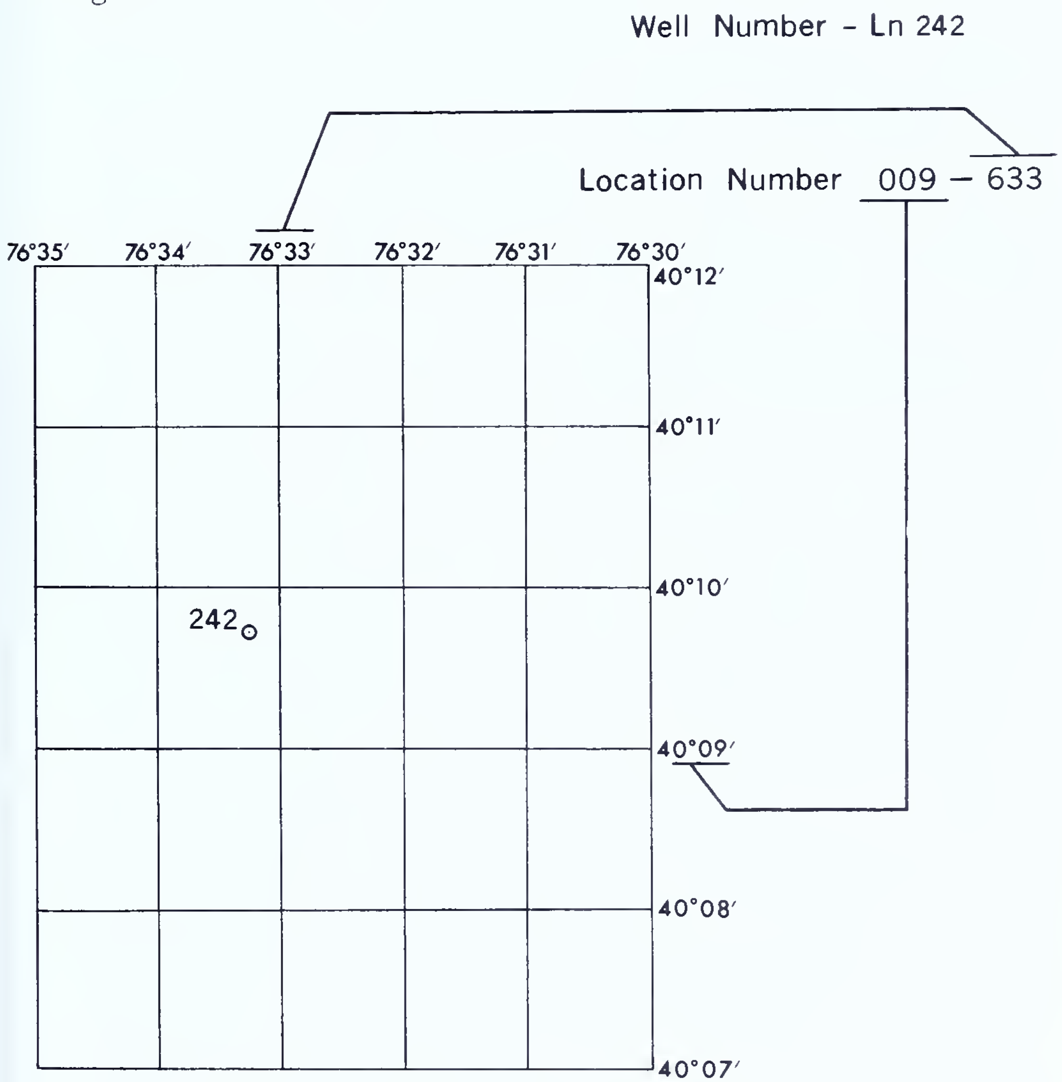


Figure 3. Sketch showing well-numbering system.

ACKNOWLEDGEMENTS

The author expresses his appreciation to the drillers, industrial concerns, private water companies, municipal water authorities, and many homeowners who supplied information or permitted the use of their wells for hydrologic measurements. Particular thanks are due to Mr. Paul Wolgemuth and Mr. Benjamin Burkholder for permitting test wells to be drilled on their properties. The author is indebted also to Mr. Preston Ney of the Elizabethtown Water Co. and to Mr. Roland Forwood of the Masonic Homes for assistance rendered in collecting hydrologic data.

GEOLOGY

TRIASSIC SYSTEM

Sedimentary rocks of Triassic age exposed in the east coast region of the United States and Canada are referred to collectively as the Newark Group. These rocks are exposed in a series of disconnected, downfaulted troughs extending from South Carolina to Nova Scotia. The largest of these troughs, in which the project area is located, extends from the Hudson River across New Jersey, southeastern Pennsylvania, and central Maryland, into Virginia. The trough is elongated mainly in a northeast-southwest direction and is bounded on one side by steeply dipping faults.

The sediments of the Newark Group were deposited by streams and rivers that discharged into these troughs from nearby uplands. Variations in topography and climate resulted in irregular deposition of lenticular beds consisting largely of poorly sorted material. The rocks are commonly red, exhibit similar lithologic, paleontologic, stratigraphic, and structural relationships, and are of continental origin. Conglomerate, sandstone, siltstone, shale, and argillite make up the bulk of the deposits. Associated with these sedimentary rocks are igneous rocks of basaltic composition that occur both as extrusive flows interbedded with the sedimentary strata and as intrusive dikes and sills. Igneous activity occurred during the late stages of deposition, and some of the dikes were intruded after deposition had ceased.

The rocks of the Newark Group are commonly subdivided into two major units, and in some troughs a third major unit is present locally. These units have been given formation names but it has not been possible to correlate formations from one trough to another. The oldest deposits in each trough are predominantly arkosic in composition. The youngest deposits in most troughs consist of red beds in which arkosic sediments are subordinate or lacking. Stratigraphically intermediate units, where present, consist of fine-grained, dark-colored sediments that are believed to have been deposited in lakes and swamps in the central parts of the troughs. These major units interfinger to some extent and thus are partly contemporaneous.

The Newark Group is believed to be of Late Triassic age, partly on the basis of correlation with Triassic rocks of Europe (McLaughlin, 1957, p. 1492-1493), and partly on the basis of structural and stratigraphic evidence. Rocks of the Newark Group lie unconformably on strongly folded and deeply eroded Paleozoic rocks and hence were not involved in the tectonic activity near the end of the Paleozoic Era. At several areas in New Jersey the deeply eroded sedimentary rocks of the Newark Group are unconformably overlain by sediments of Cretaceous age.

In the segment of the trough in which the project area is located, the Newark Group has been divided into a basal unit known as the New Oxford Formation and into an overlying and partly contemporaneous unit known as the Gettysburg Formation. The New Oxford and Gettysburg Formations are the approximate stratigraphic equivalents of the Stockton and Brunswick Formations, respectively, of eastern Pennsylvania and New Jersey.

New Oxford Formation

The following description of the New Oxford Formation is summarized largely from work by D. B. McLaughlin (1953, 1964) and by McLaughlin and Gerhard (1953). The geologic contacts and structure of the New Oxford Formation shown on the map accompanying this report (Pl. 1) were mapped by McLaughlin. Comments on jointing and weathering are the author's.

Distribution and topographic expression. — In Lancaster County, the principal segment of the New Oxford Formation occupies a narrow area approximately 31 miles in length extending from the Susquehanna River near Bainbridge to Denver. In the western one-third of this area the formation trends northeastward and has a maximum width of about 3 miles. Near Mastersonville the trend changes slightly toward the east. At the flexure the area begins to narrow eastward until, at Denver, it is less than one-half mile wide.

Arkosic rocks of the New Oxford Formation are exposed in three separate areas south and southeast of Denver. One of these, 2½ miles long and one-quarter mile wide, is just northeast of Reamstown. A larger area, about 8 miles long and ranging from 1 to less than one-quarter of a mile in width, lies between Akron and Terre Hill. Another very small segment, about three-quarters of a mile long and less than a tenth of a mile wide, underlies the village of Martindale.

The area underlain by the New Oxford Formation is a gently rolling lowland in which elevations range generally between 400 and 500 feet above mean sea level. Several low ridges parallel to the strike of the bedding formed largely by conglomerate, which is more resistant to weathering and erosion than the sandstone and shale. Many small streams flow parallel to the strike of the bedding, but the larger streams traverse the formation almost perpendicular to the strike or at an angle to it.

Lithology. — The New Oxford Formation consists of an intricately interbedded sequence of highly compacted and tightly cemented conglomerates, sandstones, siltstones, and shales. Bedding is characteristically lenticular, and individual beds grade rapidly (both laterally and downdip) into rocks of different textures. The sandstones are character-

istically subarkosic (10-25 percent feldspar content) and are the predominant rock type. Most conglomerates are in the lower two-thirds of the formation. Siltstones and shales are present throughout the formation, and most wells 100 feet or more in depth will penetrate some shale or siltstone. The sandstones and conglomerates are most commonly light gray to greenish gray where fresh, and yellowish or buff colored where weathered; a few of the sandstones are red or reddish brown. The siltstones and shales are generally red, but gray, greenish gray, and tan are not uncommon.

Beds of true arkose are present but are not abundant in the New Oxford Formation. The sandstones and conglomerates of the overlying Gettysburg Formation are distinguished from those of the New Oxford Formation by their deficiency in feldspar. In addition, the very fine-grained sandstones, siltstones, and shales of the New Oxford Formation are commonly micaceous, whereas those of the Gettysburg Formation are not.

The conglomerates of the New Oxford Formation are composed largely of angular to subrounded, sand-size grains of quartz and feldspar in which are embedded widely scattered pebbles of vein quartz and quartzite together with a few fragments of schist and other rock types. The cement is chiefly silica. At several localities near the base of the formation, limestone conglomerate is exposed or has been penetrated by wells.

The sandstones range in texture from very fine-grained to very coarse-grained, but fine- to medium-grained rocks are the most abundant. The fine-grained sandstones commonly grade vertically into siltstones. Sorting is generally poor, but some of the fine-grained rocks display fair to good sorting. Some of the fine-grained sandstones are very micaceous and display closely spaced partings parallel to the bedding planes. The sandstones are composed mainly of angular to subrounded grains of glassy quartz and white feldspar, and of minor amounts of mica. The matrix is composed of a mixture of very fine grains of quartz and feldspar together with particles of silt and clay. A few sandstones contain calcium carbonate as a cementing material, but in most sandstones this type of cement is either absent or is present in very small amounts.

Siltstones and shales are considerably softer than most of the coarse-grained rocks, and most of them are rather compact and structureless. Many of the siltstones and shales are very micaceous and many are calcareous.

Stratigraphic relations. — The New Oxford Formation is stratigraphically the lower, and therefore the older, of the two major subdivisions of the Newark Group in Lancaster County and the area to the north. However, beds of the overlying Gettysburg Formation are interbedded

with those of the New Oxford Formation so that the two units are partly contemporaneous. The upper (or northern) contact of the New Oxford is drawn rather arbitrarily where the quartzose, almost nonfeldspathic sandstones of the Gettysburg Formation predominate over the feldspathic sandstones of the New Oxford Formation. The lower (or southern) contact with pre-Triassic rocks is not exposed, but in most places it can be determined rather closely on the basis of abrupt changes in float (residual rock fragments in the soil), soil color, and topography.

Individual beds seldom can be traced along strike for any appreciable distance, but sequences of beds of distinctive lithology may persist for several miles. Several rather prominent ridge-forming conglomerate units have been mapped and are shown on the accompanying geologic map (Pl. 1).

The lithologic differences between the New Oxford Formation and Gettysburg Formation appear to have been the result of a change in source areas from which the sediments were derived. Petrologic and structural evidence indicates that the New Oxford sediments were derived principally from feldpathic igneous and metamorphic rocks to the south, whereas the sediments of the Gettysburg Formation apparently were derived principally from the relatively nonfeldspathic sedimentary rocks of Paleozoic age to the north and northeast.

Thickness. — The thickness of the New Oxford Formation in the area between the Susquehanna River and Denver ranges from about 4,800 feet near the western end to about 900 feet at the eastern end (McLaughlin 1953, 1964). South and southeast of Denver, faulting makes thickness determination difficult. However, south of Terre Hill the New Oxford Formation is estimated to have an average thickness of 500 feet (Jonas and Stose, 1926).

Structure. — The sediments of the New Oxford Formation were deposited on surfaces of relatively low to moderate gradient, but settling of the floor of the trough during deposition, and downward movement along northern border faults, tilted the beds steeply to the north or northwest. Postdepositional stresses also produced an extensive network of joints in the rocks.

In the area west of Denver, the northward-dipping beds strike northeastward in the western half of the area and eastward in the eastern half of the area. The dip of the bedding steepens from west to east, averaging between 25° and 35° west of Elstonville and between 40° and 60° east of Elstonville. A few steeper dips (70° to 80°) have been measured, but it is possible that these were measured on large-scale cross-bedding and that postdepositional tilting has caused them to become anomalously high. Bedding in the New Oxford Formation south and

southeast of Denver has a general east-west trend and a northward dip. Dips are generally greater than 20°, and in the vicinity of faults — where strikes and dips are commonly at variance with the regional trend — they may be considerably greater.

Only a few faults have been mapped in the New Oxford Formation west of Denver, but others may be present. The sparsity of bedrock exposures and the general lack of distinctive mappable lithologic units make it difficult to confirm the presence or absence of faults. The known faults are high-angle structures oriented perpendicular or diagonal to the strike and generally involve displacements of only a few hundred feet.

South and southeast of Denver the New Oxford Formation has been extensively faulted into blocks and wedges by high-angle faults that traverse the rocks both in a north-south and in an east-west direction. At several places, the New Oxford Formation is in fault contact with Paleozoic limestones and shales.

Rocks of the New Oxford Formation are jointed extensively, but the degree of development of these joints may differ considerably from bed to bed, even in rocks of similar texture and composition. Some sandstones and conglomerates are well jointed, others are rather massive and contain only widely spaced irregular joints. Shales and siltstones generally are compact and unfractured, or contain only irregular, hairline fractures. The openings formed by joints seldom exceed 1 or 2 inches in width and generally are only a fraction of an inch. The distance between joints of the same set varies from a few inches to several feet. The closest joints generally occur in micaceous sandstones in which platy partings have developed parallel to the bedding.

Joints in the New Oxford Formation between the Susquehanna River and Denver have three principal orientations. In general the best-developed set is the nearly vertical set that strikes east-northeast. Joints that parallel the bedding also are strongly developed in some beds, particularly in those containing substantial amounts of mica. A third poorly developed set of nearly vertical joints strikes approximately north-south. Because only a few joints were measured in the area south and southeast of Denver, the general orientation of joints in this area cannot be given. However, the jointing characteristics of the rocks are essentially the same as in the area west of Denver.

Weathering characteristics. — Weathering consists of a group of processes that cause the disintegration and decomposition of rocks and minerals near the earth's surface. Of all these processes, chemical weathering is generally the most effective in promoting rock decay. The principal zone of weathering occurs above the water table and within the zone of water-table fluctuations, where chemical alteration caused

by such agents as air, water, and water solutions is most intense. The intensity of weathering decreases markedly below the zone of water-table fluctuation, but its effects may extend for considerable distances below this zone.

In the area underlain by the New Oxford Formation, weathering processes have produced a thick mantle of strongly altered, loosely consolidated material. This material ranges in thickness from a few inches to as much as 50 feet. On the basis of the depths of hand-dug wells (which commonly bottom in solid bedrock) and the depths of casings in drilled wells (which generally are seated 3 or 4 feet into solid bedrock) the average thickness of the weathered mantle is estimated to be about 23 feet. The mantle is generally thinnest beneath draws and valleys and thickest beneath moderate slopes and low flat-topped ridges.

Weathering of the underlying bedrock has occurred chiefly along the walls of joints and along bedding planes, and it has been most intense in arkosic and subarkosic sandstones and conglomerates. Some highly quartzose sandstones and conglomerates, and the siltstones and shales, have been affected only slightly by weathering processes. The thickness of the weathered zones along joint surfaces in the bedrock is commonly no more than a few inches; however, some highly feldspathic beds and beds with closely spaced bedding-plane joints have been thoroughly weathered throughout their entire thickness.

The maximum depth to which chemical weathering occurs in the bedrock is not known, but data from a test well (Ln-242) drilled to a depth of 300 feet in a conglomerate sequence west of Milton Grove indicate that alteration occurs at least to depths of 155 feet. Relatively soft beds of sandstone and conglomerate containing partially altered feldspar grains were encountered at several depths between land surface and a depth of 155 feet during drilling of this well. Several large pieces of white clay, residual from the alteration of feldspars, apparently were flushed from the principal yielding zone at 155 feet during drilling.

Diabase

Diabase, an igneous rock of basaltic composition, has intruded the New Oxford and Gettysburg Formations of Lancaster County chiefly in the form of long, narrow dikes. A thick, massive sill of this rock was intruded near the upper boundary of the New Oxford Formation between the Susquehanna River and Mount Hope. The dikes dip steeply, have a north or northeast trend, and range in thickness from about 50 to 250 feet. The longest continuous dike in the New Oxford Formation is about 7 miles long. It cuts diagonally across the strike of the beds from a point north of Milton Grove to a point southwest of Elizabethtown. This dike and several others extend into the pre-Triassic rocks. In most places the

dikes have little distinct topographic expression and, because they are deeply weathered, are exposed in only a few deep road and railroad cuts. Rounded rust-covered cobbles and boulders of diabase show up rather distinctly in the soils overlying these dikes, and therefore they are fairly easily mapped on the basis of float.

Diabase in the central part of sills is medium to coarse grained, but at contacts with the country rock and in the narrow dikes — where cooling was more rapid — the texture is fine grained.

Heat emanating from the cooling diabase baked the adjacent sedimentary rocks causing them to become hard and brittle. In addition, the original red or brown color of some sediments has been changed to bluish black by reduction of the iron oxide. These effects are most pronounced in sediments near the large masses of diabase, but similar color changes and induration also have occurred adjacent to the narrow dikes. In a railroad cut at the south edge of Elizabethtown, a shale in contact with a vertical dike about 50 feet thick grades from bluish black to red about 100 feet away from the dike. A medium-grained arkosic sandstone beneath the shale was hardened for a distance of about 8 feet from the dike. The hardened rocks on either side of the dike are strongly shattered, and it is possible that these narrow baked zones are also zones of high permeability.

HYDROLOGY OF THE NEW OXFORD FORMATION

GENERAL PRINCIPLES

Ground water is the subsurface water in the zone of saturation —the zone where all the voids are filled with water under pressure equal to or greater than atmospheric. The upper surface of this zone is the water table. Above the water table is the zone of aeration, where voids are filled partly with water and partly with air.

Ground water may occur under either water-table (unconfined) or artesian (confined) conditions. Water-table conditions exist where the upper surface of the zone of saturation is not confined and is free to fluctuate in response to recharge to or discharge from the aquifer. The water table is a modified replica of the surface topography, and is therefore at higher altitudes beneath hills and ridges than beneath valleys. Artesian conditions exist where ground water is confined under hydrostatic pressure beneath a relatively impermeable bed or layer of rock. In wells cased to a confined aquifer, water levels rise above the confining layer to a level called the piezometric surface of the aquifer. Flowing wells occur where the piezometric surface is above the land surface.

Where artesian aquifers or zones extend to or near the land surface they are generally recharged by water moving downward from the water table. In such places the water undergoes a change from unconfined to confined conditions. Recharge to a confined aquifer may also be derived from an overlying or underlying aquifer in which the water is under greater hydraulic head. The rate of interaquifer flow through a relatively impermeable confining layer may be extremely slow, but when this flow occurs over large areas it may contribute a substantial part of the total recharge to an aquifer or zone. The rate of interaquifer flow may be increased if the artesian pressure in the receiving aquifer is lowered further by pumping from a well or wells.

The capacity of an aquifer to store water is a function of its porosity, which is the percentage of open space in the total volume of the aquifer. If the porosity originated at the time the aquifer was formed, it is termed primary porosity; if formed later, by such processes as jointing or weathering, it is termed secondary porosity. Unconsolidated sediments commonly have rather high primary porosity, but as consolidation takes place by compaction and cementation, primary porosity is reduced and may be eliminated completely. In highly consolidated rocks the porosity is largely of secondary origin.

The capacity of an aquifer to transmit water under hydraulic gradient is determined by its permeability. The permeability is determined by the size, shape, and number of the primary and secondary openings and by the degree to which these openings are interconnected.

In order to evaluate the capacity of aquifers to store and transmit water it is necessary to determine their hydraulic properties. These properties are generally determined from mathematical analysis of measured water-level fluctuations produced in or in the vicinity of a well during a period when it is pumped at a known rate of discharge. The following paragraphs define these hydraulic properties.

The coefficient of permeability of an aquifer is a measure of the aquifer's ability to transmit water and is defined as the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot under a unit hydraulic gradient at a temperature of 60° F.

The coefficient of transmissibility, T, of an aquifer is defined as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a unit hydraulic gradient.

The storage coefficient, S, of an aquifer is defined as the volume of water the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Specific capacity is defined as the yield of a well per unit decline of water level. It is expressed generally in gallons per minute per foot of drawdown.

Specific capacity is in part a function of the hydraulic properties of an aquifer, and because of this relationship it can be used as a tool for comparing different aquifers. High specific capacities generally indicate high coefficients of transmissibility, and low specific capacities indicate low coefficients of transmissibility. It is not a precise tool, however, because specific capacity is also related to the radius and efficiency of the well, the rate and duration of pumping, and the depth of penetration of the aquifer.

Where a well penetrates more than one aquifer, the specific capacity will increase as each new aquifer is intercepted, and the increase will be approximately equal to the specific capacity of a well tapping the new aquifer alone. In other words, the specific capacity of a multiaquifer well is equal to the sum of the specific capacities of the individual aquifers (Bennett and Patten, 1960).

OCCURRENCE OF GROUND WATER

Ground water in the New Oxford Formation occurs chiefly in openings developed along joints and in intergranular openings formed where weathering processes have resulted in decomposition and disintegration of the consolidated rock. Porosity of primary origin appears to have been largely obliterated by compaction and cementation. Fresh rocks observed in surface exposures and in cuttings from numerous drilled wells were invariably tightly cemented and highly compacted.

In the weathered mantle overlying the bedrock, water occurs largely in intergranular openings. The mantle is highly porous and therefore constitutes an important ground-water storage reservoir that supplies large amounts of recharge to the bedrock. In areas where recharge from streams is not available, much of the water pumped from drilled wells is derived from storage in the overlying mantle. The saturated portion of the mantle is a direct source of water to most hand-dug wells, but most of these wells were reported to yield only small to moderate supplies. Apparently the clay minerals produced by the intense alteration of feldspars have partially clogged the pore spaces of the weathered mantle, causing it to have a low permeability.

The saturated thickness of the weathered mantle varies considerably from season to season, being greatest in the winter and spring months and least in the summer and autumn months. Measurements made in 58 hand-dug wells at different times of the year, at different topographic positions, indicate that the saturated thickness of the weathered mantle ranges from 0 to 24 feet and averages approximately 6 feet. During late

summer droughts, the mantle overlying some ridges and steep slopes becomes nearly or completely dewatered as ground water drains to points of lower elevation. In this way, many hand-dug wells in the New Oxford Formation become dry, or nearly so, during droughts. Dewatering of the mantle may also occur in the vicinity of heavily pumped drilled wells.

In the bedrock, water is contained in both fracture-induced and weathering-induced porosity. Sandstones and conglomerates, which have been more strongly fractured and weathered than siltstones and shales, are the principal water-yielding rocks. Siltstones and shales, which have been relatively unaffected by weathering processes, generally contain only poorly developed fractures; therefore, they yield little or no water to wells.

Wells drilled into the bedrock generally obtain the bulk of their water from thin, widely spaced zones of relatively high permeability. These zones are commonly only a few inches thick and seldom are more than 2 or 3 feet thick. They are generally separated, vertically, by several feet or several tens of feet of rock that yield little or no water directly to the well. The principal water-yielding zones have developed in beds, or zones within beds, that apparently have been more thoroughly fractured and weathered than overlying and underlying rocks. These zones are oriented parallel to the bedding planes and, like the beds, are of small areal extent. Moreover, observations made during drilling of a few closely spaced wells indicate that the permeability of individual water-yielding zones may differ considerably over distances as short as 100 feet. The occurrence of water-yielding zones is erratic, and their presence generally can be determined only by drilling.

An example of the erratic occurrence of water-yielding zones is provided by information from three wells owned by the Bainbridge Water Authority. A geologic cross section constructed from driller's logs of these three wells, which shows the depths at which water was encountered, is shown in Figure 4. The fractures that connect these zones are not shown. The altitude of the water table was determined from a nearby dug well, a nearby spring, and a stream.

The openings along fractures and the intergranular openings produced by weathering along fractures and bedding planes compose but a very small fraction of the total volume of rock; hence, the porosity of the bedrock is very low. These openings serve primarily as conduits through which water it transmitted from points of recharge to points of discharge.

Weathering processes have produced a minor increase in the porosity of the bedrock, but in some highly weathered arkosic or subarkosic sandstones and conglomerates, clays produced by the alteration of feldspars appear either to have reduced the permeability of the rock or to have

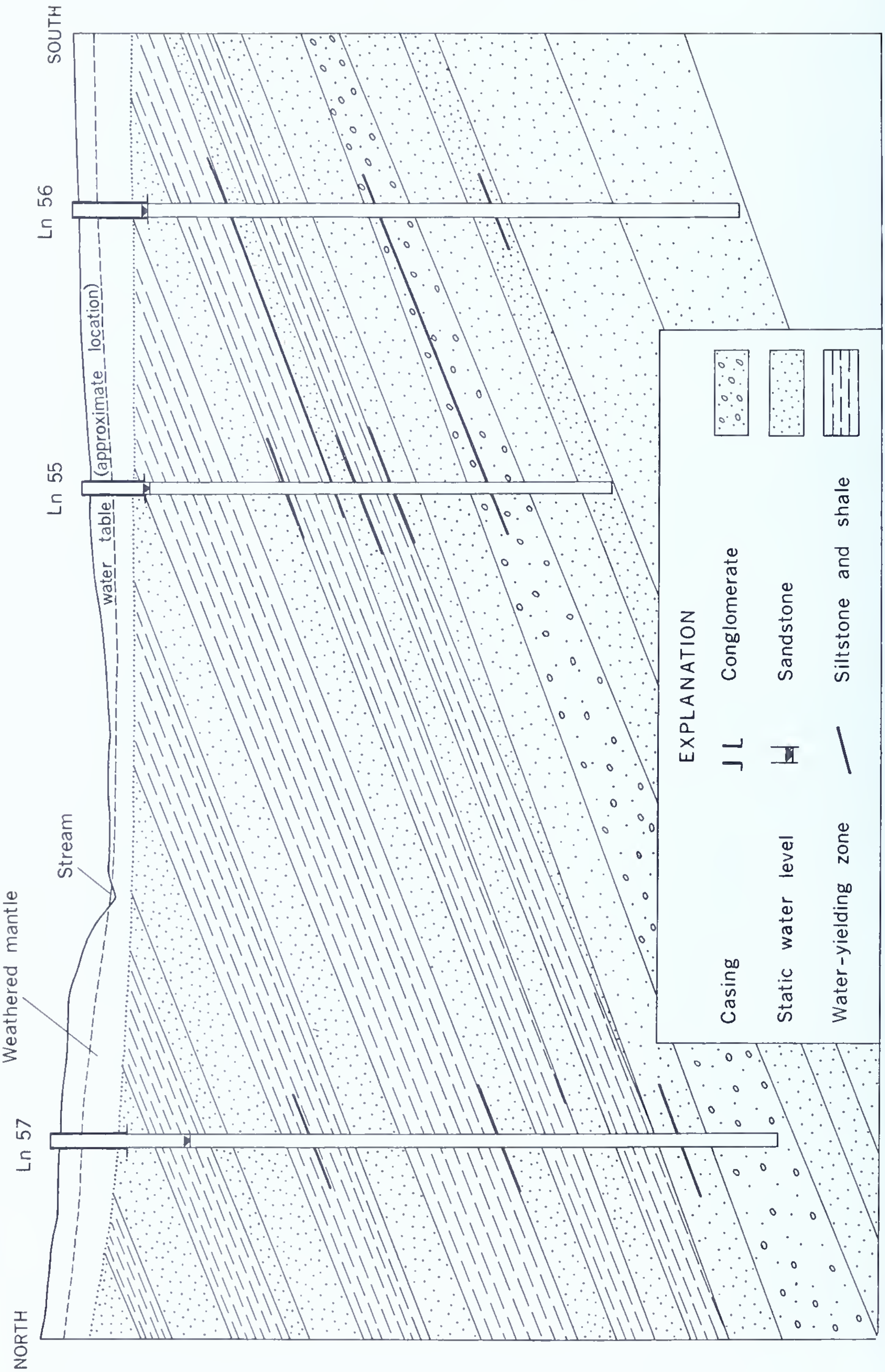


Figure 4. Geologic section constructed from driller's logs of three wells near Bainbridge, Pa., showing stratigraphic positions of water-yielding zones.

prevented any significant increase in permeability. Some wells penetrate several beds or zones of soft weathered rock that yield little or no water. In other weathered feldspathic rocks, relatively high-yielding zones occur, and the permeability of these zones appear to be related partly to weathering.

A few sandstones contain significant amounts of calcium carbonate as cementing material. Calcium carbonate is highly soluble, and its removal by circulating ground water makes the sandstones both more porous and more permeable. A log of well Ln-265, which is given in Table 6, shows that several fine-grained sandstones penetrated by the well are cemented with calcium carbonate, and it is possible that some of the yielding zones owe their permeability to the removal of this cementing material.

Ground water occurs under water-table (unconfined) conditions in the mantle and generally under artesian (confined) conditions in the bedrock. However, the unconfined and confined zones are intimately interconnected in one continuous hydraulic system. The major conduits are connected to each other and to the water table by the extensive system of joints that cut the rocks.

MOVEMENT OF WATER

Ground water moves in the direction of decreasing hydraulic gradient from areas where the water table or artesian head is high to areas where it is low. In the New Oxford Formation the flow pattern is essentially local and is controlled largely by the configuration of the land surface. Thus, most of the water moves from high topographic areas to nearby streams, where it is discharged. Some of the water entering the ground from precipitation may flow from points of recharge to streams completely within the weathered mantle, but much of the water moves downward and flows to streams through the complex network of fractures and weathered zones in the bedrock. The proportion of flow through the mantle is determined by the relative transmissibilities of this material and the underlying bedrock. Where the transmissibility of the bedrock is higher than that of the mantle, a greater portion of flow will move to points of discharge through the bedrock.

Most of the beds contain fractures through which some water can move, but some beds of sandstone and conglomerate contain much better developed fractures and weathered zones than others. The permeability of the bedrock as a whole is generally highest parallel to the plane of the bedding and lowest perpendicular to the plane of the bedding. The least permeable rocks are the beds of siltstones and shale, which are generally lenticular, and although some water may move across these beds, the bulk of water is believed to flow around them to areas where they grade into more permeable sandstones. Numerous permeable zones

encountered in wells at contacts with siltstones or shale may be zones where flow is being shunted around these beds.

Water-level data from wells indicate that, in most areas, ground water discharges into streams that traverse the area. In a few areas, however, water levels in drilled wells near a stream are substantially below the level of the stream, indicating that water in the bedrock is not being discharged into the stream at these localities. The discharge is occurring either into a downstream reach of the stream or into a larger stream of the surface-drainage system.

Near Bainbridge, for instance, water levels in three drilled wells (Ln-55, 56, and 57) near a small intermittent stream are below stream level (Fig. 4) but above the level of the nearby Susquehanna River. Ground water in the bedrock is apparently being discharged directly into the river.

Movement of ground water through the loosely consolidated weathered mantle is probably less complex than it is in the consolidated bedrock. However, since the texture and composition of the mantle are determined partly by the texture and composition of the underlying bedrock, directional variations in permeability probably occur in the weathered mantle also. Where the mantle is derived from shale or siltstone, its permeability may be much lower than where it is derived from sandstone. Hence, water that cannot enter the bedrock would tend to flow around or over the less permeable material. In some places, movement of ground water over mantle material derived from siltstone or shale may result in the formation of a spring. Springs occur also where the thickness of the weathered mantle decreases sharply.

RECHARGE

The capacity of the New Oxford Formation to store water is small; consequently water levels decline rapidly under pumping conditions and the formation must be replenished frequently by recharge or the decline soon becomes excessive — even though much of the water pumped is diverted from natural discharge. Most of the recharge is derived from precipitation that falls directly on the formation, but a small amount is derived from subsurface inflow from adjacent formations that are topographically higher. Recharge also may be obtained from streamflow in areas where pumping from a well or wells reverse the hydraulic gradient and causes water to flow from the stream into the ground. Under natural conditions, however, streams generally serve as lines of discharge from the ground-water reservoir.

Approximately 40 inches of precipitation falls on the project area annually. Of this amount, part runs off directly to streams, part is returned to the atmosphere by evaporation and transpiration, and part infiltrates

to the water table. The amount of precipitation that reaches the water table is affected greatly by evapotranspiration rates, but such factors as the moisture-holding capacity of the soil, the infiltration capacity of the soil, the rate and duration of precipitation, the rate of snowmelt, and the slope of the land surface also exert important controls on the amount that becomes recharge.

During the growing season (April to October), evaporation and transpiration processes may return to the atmosphere most of the precipitation that does not run off directly to streams. As a result, recharge to the ground-water reservoir during growing seasons is sharply reduced. During the nongrowing season (November to March), when evapotranspiration rates are low, most of the rainfall or snowmelt that does not become surface runoff may percolate to the water table.

The effect of evapotranspiration on the recharge-discharge regime of the ground-water reservoir is demonstrated by the hydrograph shown in Figure 5. This hydrograph is of well Yo-180, in the New Oxford Formation in York County, approximately 5 miles southwest of the western end of the project area. Although the magnitude of the fluctuations may differ, the seasonal pattern of water-level fluctuations in this well is typical of those occurring in drilled wells throughout the New Oxford Formation in Pennsylvania. Declining water levels indicate that discharge from the ground-water reservoir exceeds recharge to it; rising water levels indicate the reverse — that recharge exceeds discharge. The hydrograph shows that the bulk of ground-water recharge occurred during the nongrowing seasons, and that recharge during the growing seasons was infrequent and generally small — despite the fact that precipitation was fairly evenly distributed throughout the period of record.

The soil zone acts as a major barrier to ground-water recharge during the growing season. The soil has the ability to retain several inches of water in the form of soil moisture, and until the soil becomes saturated no water percolates through it to the water table. The water-holding capacity of the predominantly sandy soils of the New Oxford Formation has been estimated to be 2 to 6 inches, depending on the type and thickness of the soil (Carey, 1959, p. 120-121).

During the growing season this soil moisture is removed at such a high rate by plant transpiration that the soil is unsaturated much of the time. Saturation of the soil and subsequent infiltration of water to the water table occur generally after periods of intense or frequent rainfall. The hydrograph in Figure 6 shows, for example, that most of the recharge during the 1961 growing season followed a 2-week period in July when rainfall totaled more than 3 inches. Recharge occurred also after a similar 2-week period in September and October of 1962, during which rainfall totaled more than 4 inches, but because of a greater

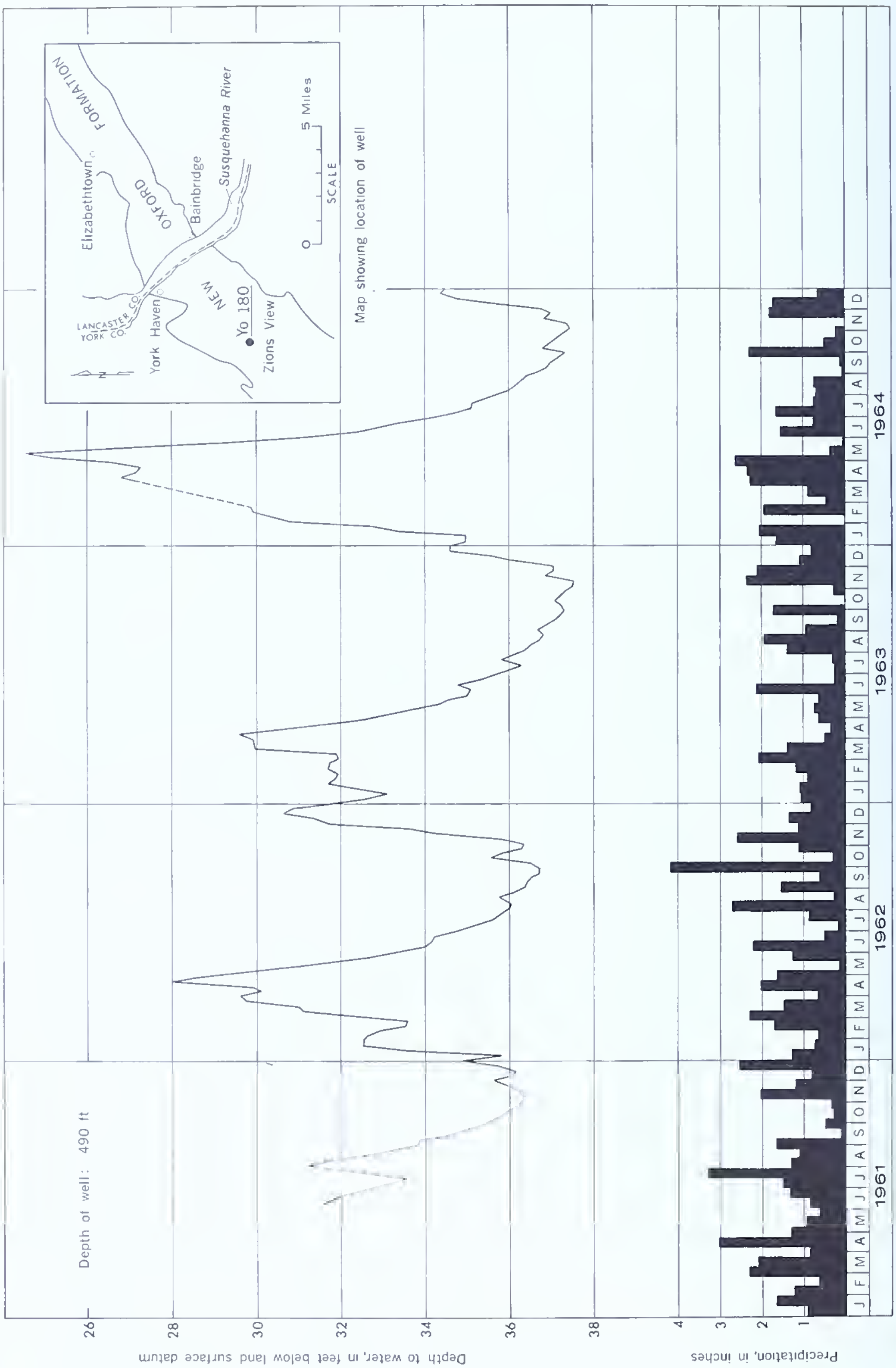


Figure 5.—Hydrograph of well Yo 180 and bar graph showing precipitation at York Haven, Pa.

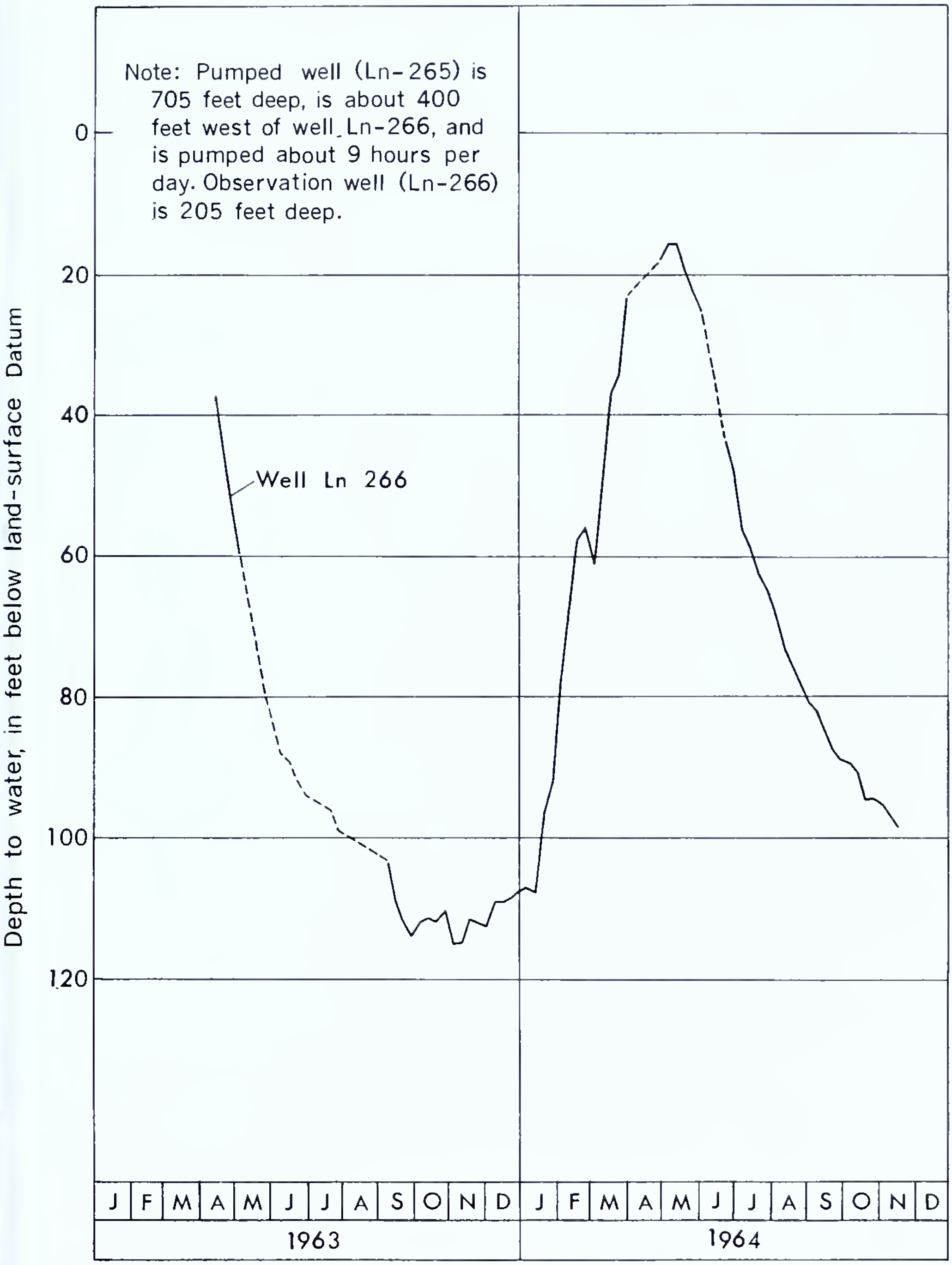


Figure 6. Hydrograph of well affected by pumping from a nearby public-supply well.

soil-moisture deficiency in September and October 1962 than existed in July 1961, a much smaller fraction of the precipitation passed through the soil zone. The rise in water level in 1962 was therefore only about half as much as it was in 1961.

At the end of many growing seasons soil moisture is so depleted that several inches of rain must fall before any ground-water recharge can occur. As a result, water levels may continue to decline after the end of the growing season even though there has been some precipitation. Similarly, the rising trend of water levels during the nongrowing season many continue into the early part of the growing season if rainfall is above average or if evapotranspiration rates are held in check by cool air temperatures.

Effects of droughts on water levels — Ground-water levels may decline below normal growing-season droughts because of the complete or nearly complete cessation of recharge from precipitation. However, since recharge is low during the growing season anyway, such droughts generally cause water levels to be only slightly lower than normal. Some shallow dug wells and low-yielding springs may go dry near the end of a growing season having below-average precipitation, but drilled wells used for domestic and other low-requirement purposes are seldom adversely affected.

The yields and pumping levels of heavily pumped wells generally decline more during growing seasons when drought conditions prevail than during growing seasons when precipitation is normal. Lower ground-water levels caused by lack of recharge are partly the cause of these declines, but in many places the declines are caused chiefly by the increased pumping required to meet increased demands for water.

The effect of successive growing-season droughts on ground-water levels is shown by the hydrograph of well Yo-180 in Figure 5. Table 1 shows that precipitation at York Haven, Pa., during the growing seasons of 1961 through 1964 ranged from 4.90 to 13.52 inches (19 to 54 percent) below normal. The hydrograph in Figure 5, however, shows that only a small net decline in the water level occurred between 1961 and 1964. The maximum depth to water in 1964 was less than 1 foot greater than the maximum depth recorded in 1961. Moreover, the highest level in this well during the period of record occurred near the beginning of the 1964 growing season.

A comparison of the hydrograph in Figure 5 with the precipitation summary in Table 1 indicates that relatively large variations in water levels may occur during the winter and spring months as a result of rather small variations in total precipitation during those months.

Effect of heavy pumping on water levels — The principal artesian zones in the New Oxford Formation are discontinuous, limited in areal extent, and poorly interconnected hydraulically. As a result, the effects of pumping a well are transmitted rapidly in the area adjacent to the well, but the cone of influence expands very slowly away from this area.

Table 1. Departure from average precipitation at York Haven, Pa., during periods corresponding approximately to the growing and nongrowing seasons, 1961-64.

Period	Average precipitation 1931-55 (inches)	Departure from average precipitation (inches) 1961	1961-62	1962	1962-63	1963	1963-64	1964
April to October	25.27	-6.87		-4.90		-13.52		-10.32
November to March	14.62		+0.25		-0.41		+2.04	
January to December	39.89	-5.76		-4.65		-13.87		-9.89

Water levels in some wells only a few hundred feet from a heavily pumped well may be affected only slightly, or not at all, even after several years. Because of this inability of wells to draw from storage for any appreciable distance, large withdrawals during periods of low recharge, as during most growing seasons, generally result in considerable dewatering of the bedrock and weathered mantle near the well.

Although the yields of production wells decrease and increase with seasonal ground-water depletion and replenishment, none of the existing production wells are reported to be continuously decreasing in yield, and there is no evidence of steadily declining water levels in the vicinities of these wells. The fact that most of the existing production wells are located near streams, from which they induce recharge, is probably the reason that continuous depletion of ground-water storage has not occurred. Nevertheless, annual recharge is apparently about in balance with combined artificial and natural discharge in the vicinity of the few production wells that are relatively distant from streams, as they had shown no persistent declining trends at the end of 1964.

The magnitude of aquifer dewatering during the growing season and subsequent replenishment during the nongrowing season in the vicinity of a heavily pumped production well is illustrated by the hydrograph of well Ln-266 shown in Figure 6. This well is 205 feet deep and is affected by pumping from well Ln-265, which is 705 feet deep and approximately 400 feet to the west. Both wells are owned by the Elizabethtown Water Company and are near a small stream, at the western edge of Elizabethtown. During the summer and fall, upstream diversion from the stream to a nearby reservoir often reduces the streamflow to a trickle. Well Ln-265 is pumped about 9 hours daily throughout the year, the discharge varying from an average of about 200 gpm during the winter and spring

to an average of about 170 gpm during late summer and fall. The hydrograph shows that the water level in the observation well declined more than 70 feet, to approximately 115 feet below land surface, during the growing season of 1963. However, natural recharge from precipitation and induced recharge from the stream during the winter and spring of 1963-64 was so far in excess of the combined natural and artificial discharge that the water level rose to within 16 feet of the surface in the spring of 1964, indicating that nearly complete refilling of the surrounding rocks had occurred.

A comparison of this hydrograph with that of well Yo-180 in Figure 5 for the same period of time shows that the pattern of seasonal fluctuations of water levels in both wells is almost identical — the principal difference being the greater magnitude of the water-level decline in well Ln-266, which was caused by the pumping from well Ln-265.

DISCHARGE

Ground water is discharged from the New Oxford Formation both naturally and artificially, although artificial discharge, which consists chiefly of withdrawal through wells, constitutes only a small fraction of the total volume discharged annually. Most of the natural discharge occurs by movement of ground water into streams, and springs. In addition, some ground water is discharged into adjacent formations, and some is discharged to the atmosphere by evaporation and transpiration.

The flow of all perennial streams contains a component of groundwater inflow, and during extended periods of dry weather the flow of unregulated streams is sustained almost entirely by ground-water inflow. The rate at which ground water is discharged into a stream is directly proportional to the hydraulic gradient between points of recharge and points of discharge along the stream. Consequently, during the winter and spring, when rising water levels cause an increase in the hydraulic gradient, the discharge of ground water to streams is greatest.

Ground-water discharge by evaporation may occur where the capillary fringe above the water table extends to the surface, but in most areas underlain by the New Oxford Formation, the water table is far enough below land surface that discharge by this means is small or nonexistent.

Discharge from the ground-water reservoir by plant transpiration occurs in areas where plant roots extend to the water table or to the capillary fringe overlying the water table. Throughout most of the area underlain by the New Oxford Formation, the vegetation consists of shallow-rooted crops and plants whose roots do not extend to the water table or to the capillary fringe. Most of the ground-water discharge by transpiration occurs in the few wooded areas where tree roots extend to the zone of saturation.

Very few records are available from which to estimate the volume of ground-water discharge by wells. However, on the basis of the data available, it seems unlikely that pumpage from the New Oxford Formation in Lancaster County exceeds 1 million gpd (gallons per day). Records of water sales by three public distribution systems, which supply the communities of Akron, Elizabethtown, and Rheems, indicate that their combined pumpage from wells in the New Oxford Formation in 1962 averaged about 300,000 gpd. Pumpage from domestic wells and the small number of industrial, institutional, and commercial wells in the New Oxford Formation probably did not exceed 700,000 gpd.

Much of the water pumped in areas not serviced by a public sewer system is returned to the ground by way of septic tanks or cesspools. A large part of the water discharged into septic-tank drain fields is consumed by evaporation and transpiration, but some of it infiltrates to the water table. During the winter and spring, when evapotranspiration losses are low, most or all of this water may infiltrate to the water table.

WELLS

CONSTRUCTION METHODS

Almost all the drilled wells in the New Oxford Formation have been drilled either by the cable-tool method (also referred to as "percussion" or "churn-drill" method) or by the air-rotary method. Prior to 1958, wells were drilled almost exclusively by the cable-tool method.

In the cable-tool method a string of heavy drilling tools with a cutting bit at the bottom end is suspended on the end of a cable from a derrick. This string of tools is lifted and dropped to produce a cutting or drilling action at the bottom of the hole. The drill cuttings are removed periodically from the bottom of the hole by a long cylindrical tube known as a bailer. The yield of the well is measured periodically during drilling by determining the number of gallons that can be bailed from the well in a given period of time. Yields determined in this manner are imprecise, but it is possible to obtain approximate measurements of the drawdown by the method — thus providing a rough measure of the specific capacity of the well. The maximum rate at which a well can be bailed depends on the size of the bailer, the depth to water, and the skill of the driller. The maximum rates at which wells in the project area have been bailed are on the order of 25 to 30 gpm.

Drilling by the air-rotary method is accomplished by the rotation of a string of drilling pipe to which is attached a cutting bit. As the bit is rotated, compressed air is forced down the inside of the drill stem, out through the bit, and back up the hole between the drill stem and the borehole wall. As the air rises from the bottom of the hole, drill cuttings

and water are forced upward and are expelled onto the ground near the well. The rate at which water is discharged from the well can be determined fairly accurately, but since the borehole is completely filled with water, the drawdown cannot be measured. The depth of water-yielding zones penetrated during drilling can be determined by noting the depth at which abrupt changes in discharge occur.

Steel casing is commonly installed in drilled wells as soon as the hole has penetrated the first few feet of solid bedrock, unless additional casing has been requested or more casing is needed to prevent caving at some greater depth. The borehole below the casing is then drilled to a slightly smaller diameter. Casing depths in 225 drilled wells for which casing data are available range from 4 to 180 feet, but only 19 percent of the wells are cased to depths of more than 50 feet; the median depth of the casings is 27 feet. In a few wells the annular space between the casing and the borehole has been filled with cement, or with finely ground limestone, but in most wells this space has been filled with drill cuttings from the well. Generally, the material used to fill the annular opening has been added at the top and allowed to settle around the casing. The most common practice is to allow drill cuttings to wash into the annular openings as the well is being drilled.

DEPTHS

The depths of 377 drilled wells for which depth data are available range from 27 to 705 feet. Eighty percent of these wells are between 50 and 150 feet in depth, and only 10 percent exceed 200 feet. Most of the depths were reported by the well owner or were obtained from the driller's record.

The depths of 65 dug wells for which depth data are available range from 7 to 70 feet. The median depth is 24 feet. Dug wells generally penetrate the entire thickness of the weathered mantle and commonly bottom on the bedrock surface.

YIELDS

The reported yields (Table 4) for most domestic, stock, and commercial wells are based on brief tests made by the driller at the time the well was completed. These tests commonly were no more than one-half hour long, and the drawdown during most tests either could not be determined or was not recorded. Drawdowns for a few wells tested by bailing are given in the remarks column of Table 4. The yields reported for public-supply wells and for some industrial and institutional wells are either average long-term yields or are based on pumping tests of several hours' duration; they are therefore considered to be representative of the maximum yields obtainable from drilled wells in the New Oxford Formation.

Yields of wells in Triassic sedimentary rocks decrease considerably during extended periods of pumping. Most of the wells listed in Table 4 would probably decrease in yield by as much as 50 percent or more under conditions of sustained pumping over a period of several weeks. Data from production wells in the New Oxford Formation west of the project area and from wells in other Triassic formations to the east indicate that the average long-term yields of these wells are commonly no more than one-half to one-third of the initial yields (Rima, 1955; Barksdale and others, 1958; Wood and Johnston, 1964). Two wells (Ln-151 and Ln-265) owned by the Elizabethtown Water Co., for example, were initially tested at 450 gpm. The yield of well Ln-151 now averages 300 gpm, and that of well Ln-265 averages about 180 gpm.

More than 80 percent of the wells in Table 4 are domestic wells or wells used for purposes for which a yield of about 10 gpm is generally adequate. Few of these wells were drilled below depths at which 10 or 15 gpm was obtained; as a result, these data do not necessarily indicate the maximum capacity of the formation to yield water to wells. The yields of 319 wells for which yield data were available range from less than 1 gpm to 330 gpm, and the median yield is 12 gpm. Only about 8 percent of these wells yield more than 50 gpm, and only 4 to 5 percent yield more than 100 gpm.

Relation of well yields to stratigraphy — A comparison of the yields of wells less than 300 feet deep in the New Oxford Formation west of Denver indicates that wells in the upper (northern) part of the formation yield, on the average, slightly more than those in the lower (southern) part of the formation. The formation is divided roughly into an upper and a lower half by a conglomerate unit that occupies a central position in the formation throughout most of the area west of Denver. The median yield of 123 wells in and north of this conglomerate unit is about 14 gpm, and the median yield of 86 wells south of the conglomerate unit is about 10 gpm. Moreover, 10 of 123 wells in the upper half of the formation yield more than 50 gpm, and 4 of these wells yield more than 100 gpm, whereas only 3 wells in the lower half yield more than 50 gpm, and none yields as much as 100 gpm. A few other wells that yield 50 gpm or more are in the upper part of the formation, but these wells are more than 300 feet deep. As only one well in the lower part of the formation is more than 300 feet deep, wells deeper than this were not used in the comparison.

Field examination of several outcrops in the lower and upper parts of the formation revealed no marked lithologic or structural difference that would explain the somewhat higher permeability of the upper part.

Relation of well yields to topography — No well-defined relationship was found between well yield and topographic position of wells. Most of the few high-yielding wells are near streams, but some are on ridges and slopes. The ratios of yield to depth of wells in the same depth ranges (27 to 100, 101 to 200, and 201 to 300 feet) were compared to determine if the yield per foot of well depth was higher near streams than in other topographic positions, but no significant differences were found. Nevertheless, stream valleys are generally more favorable sites for production wells than are hills and ridges, because a well near a perennial stream may obtain significant quantities of induced recharge from streamflow. If the hydraulic connection between the well and the stream is good, the recharge induced during periods when ground-water levels are low will result in smaller declines in yields and pumping levels than commonly occur during these periods.

Yields of wells near diabase dikes — A few higher-than-average yielding wells are near the long, narrow diabase dikes that cut the New Oxford Formation. Although evidence is meager, there are indications that a narrow zone of permeable rock may exist in some places along the margins of these dikes. At one of the rare exposures of a dike, in a railroad cut at the south edge of Elizabethtown, a baked zone a few feet wide is strongly shattered and weathered. The persistence of such zones along the margins of these dikes, some of which are several miles long, may give rise to nearly vertical zones of considerable linear extent that are capable of storing and transmitting relatively large volumes of water. A high-yielding (up to 300,000 gpd) well (Ln-151) owned by the Elizabethtown Water Co. is just north of the above-mentioned dike. The high productivity of this well may be related in part to the presence of a highly permeable zone along the dike, as the beds penetrated by the well are intercepted by the dike a short distance updip from the well.

Yields of wells near faults — Movement of rock masses along a fault plane may produce a zone of intensely fractured rock along the fault, thereby giving rise to a linear zone of high permeability. Data on a few wells near faults in the New Oxford Formation south of Denver indicate that highly permeable zones do exist near some faults. Several high-yielding wells are on or near faults in the New Oxford Formation at the edge of the borough of Akron. Three of these wells (Ln-219, 221, and 222), are 82, 126, and 135 feet deep and yield 185, 250, and 250 gpm. Two other wells (Ln-214 and 215), drilled about 50 feet apart at a fault contact with shale of Ordovician age, also have high yields. Ln-214, which is 571 feet deep, yields 50 gpm; Ln-215, which is 339 feet deep, yields 150 gpm. Driller's logs indicate that both wells yield water at several depths, and both apparently penetrate the Ordovician shale. A

driller's log of Ln-214 indicates that this well penetrates about 250 feet of Ordovician shale but that no water enters in the lower 217 feet.

The importance of fault zones as potential sites for wells in the New Oxford Formation west of Denver is not known, because relatively few faults have been mapped in that area.

Relation of well yield to depth — Although the yield of deep wells in the New Oxford Formation is generally greater than that of shallow wells, no consistent relationship exists between yield and depth. Some wells as deep as 300 feet may yield less than 5 gpm; others drilled to depths of less than 100 feet may yield 50 gpm or more. Moroeover, considerable variation in yield may occur in closely spaced wells of similar depth that penetrate the same sequence of beds. For example, well Ln-55, which is 182 feet deep, yields 100 gpm, whereas well Ln-56, drilled 90 feet away to a depth of 222 feet, yields only 35 gpm. Both wells are 6 inches in diameter and penetrate nearly the same strata (see Fig. 4).

The frequency of yields that can be expected from wells drilled to a given range of depth is indicated by Figure 7. The frequency curve for wells 100 feet or less in depth shows, for example, that 47 percent of the wells drilled within this depth range can be expected to yield 10 gpm or less, and that 90 percent can be expected to yield 30 gpm or less.

The lower three curves on Figure 7, which are probably more representative of the formation as a whole than the uppermost curve, show that yields generally will increase slightly to moderately as the depth increases within the ranges shown. For example, 10 percent of the wells 27 to 100 feet deep yield more than 30 gpm, whereas 25 percent of the wells 201 to 300 feet deep yield more than 30 gpm.

The frequency curve showing the percentage distribution of yields in wells deeper than 300 feet is based on a rather small sample of wells, most of which are large-diameter wells in the upper (northern) half of the New Oxford Formation in or near Elizabethtown. The locations of a few of these deep wells were established on the basis of recommendations made by professional geologists. The curve may be used as an indication of the probability of yields that can be expected from properly located large-diameter wells drilled to depths of more than 300 feet, but whether the curve should apply to the entire formation is uncertain. Few wells deeper than 300 feet have been drilled in many parts of the formation. However, since there appears to be no significant areal differences in permeability at shallow depths, the percentage distribution of yields of wells deeper than 300 feet probably would be about the same throughout the formation.

The graph indicates that about 50 percent of the wells drilled deeper than 300 feet can be expected to yield 100 gpm or more. This pereentage is probably much too high for wells located at random within the

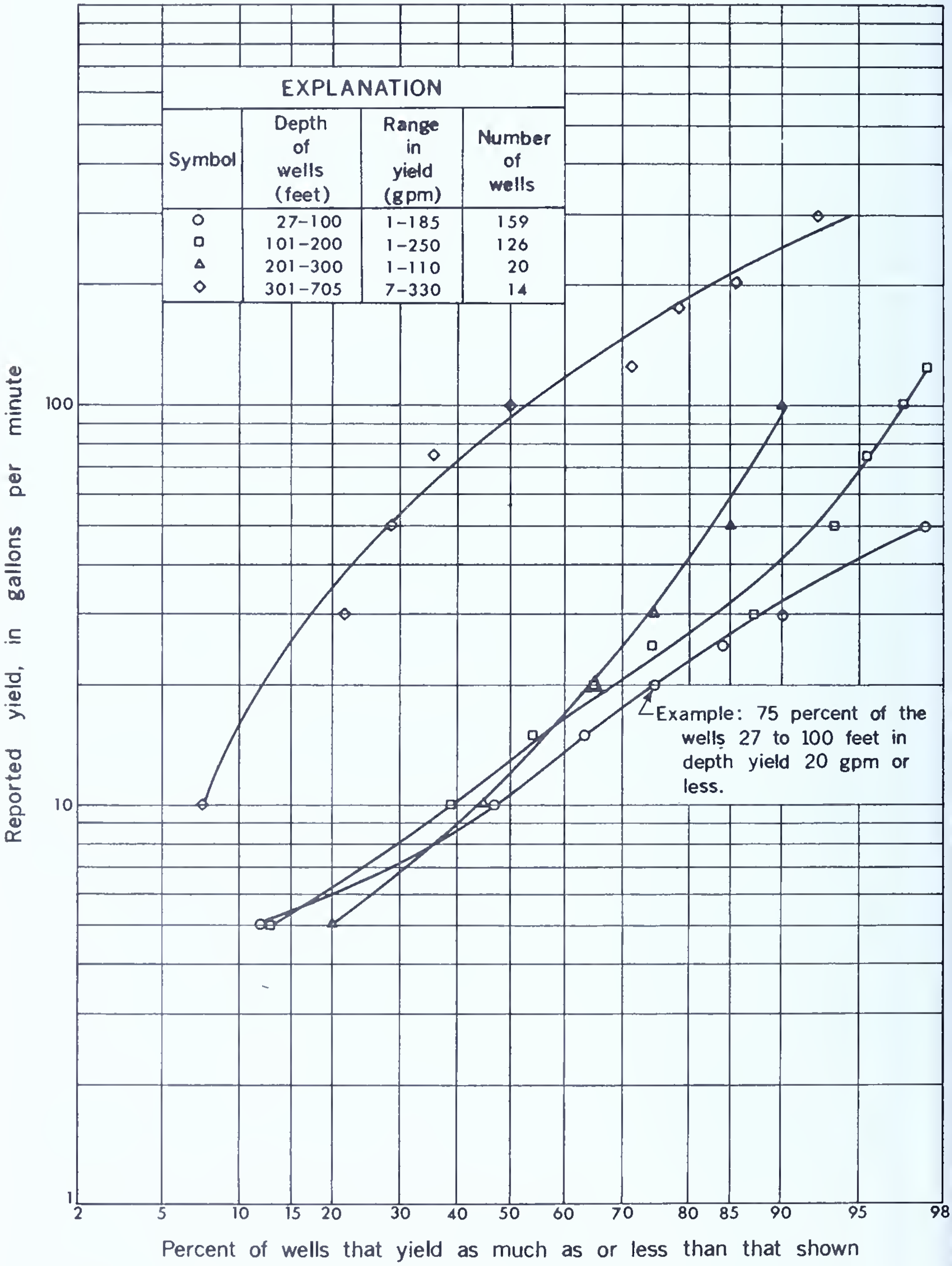


Figure 7. Cumulative-frequency graph of well yields within a given range in depth.

formation, and it may be a little high even for wells located with the aid of professional advice. Nevertheless, the chances of obtaining good wells in the New Oxford appear to be best if the wells are drilled deeper than 300 feet.

The specific depth at which wells can be expected to obtain significant quantities of water is not known. Water is reported to enter three wells at depths below 300 feet, and in the deepest known well (Ln-265) in the formation one or more high-yielding zones were penetrated between depths of 500 and 705 feet. After this well was drilled to a depth of 500 feet, it was pumped for 8 hours at 187 gpm; the drawdown was about 190 feet. After being deepened to 705 feet, the well was tested for 8 hours at 450 gpm, and the drawdown was about 155 feet. Hence, the specific capacity of this well was nearly tripled by deepening the well from 500 to 705 feet. Although it is possible to obtain water below 500 feet elsewhere in the formation, it may be advisable to drill another well into a different sequence of rock rather than to continue drilling a well below 500 feet.

SPECIFIC CAPACITY

Specific capacity, the yield per unit of drawdown in a well, is useful for comparing the relative yielding abilities of wells of different depths or diameters and of wells in different topographic or geological settings. Specific capacities of wells pumped at the same rates for the same lengths of time — especially if the wells are of similar depth and diameter — may be used also to detect differences in transmissibility of different parts of an aquifer or between different aquifers.

The specific capacities of 36 wells in the New Oxford Formation are listed in Table 3. Analysis of these data shows no significant relationships between specific capacity and the topographic and stratigraphic positions of wells. The specific capacity of a well generally increases as the well is deepened, but there is no well-defined relationship between specific capacity and well depth. Significantly different specific capacities were determined for closely spaced wells of about the same depth and diameter, and some of the lowest specific capacities were those of deep wells. Some of the highest specific capacities given in Table 3 are of wells located on faults east of Akron (see wells Ln-215, 219, 221, and 222). The data from these wells indicate that the transmissibility of the formation near these structures is high relative to other parts of the formation. Measurements made in a few wells at different rates and durations of pumping indicate that specific capacities may decrease significantly if the rate and time of pumping are increased.

Specific capacities of wells in the New Oxford Formation are generally low, indicating that the transmissibility of the formation as a whole

is also low. The specific capacities of 26 of the wells listed in Table 3 were determined from 1-hour tests at rates of 4 to 27 gpm, in order to minimize the effects of time and rate of pumping. All but 4 of these wells are 6 inches in diameter. The specific capacities determined from these tests range from 0.2 to 57.6 — but the median value is only 0.7, and only 5 wells had specific capacities greater than 3.0. At higher rates of discharge, or after longer periods of pumping, the specific capacities of most of these wells would be considerably lower. Well Ln-222, for example, had a specific capacity of 57.6 at the end of 1 hour of pumping at 24.2 gpm, but at the end of 72 hours of pumping at 250 gpm the specific capacity was only 13.9.

The specific capacities of 13 of the wells in Table 3 were determined from tests of several hours' duration, at rates ranging from 50 to 450 gpm. They range from 0.2 to 13.9, and the median is 1.2. However, if data from 4 wells (Ln-214, 215, 219, and 222) on faults are excluded, the range is from 0.6 to 3.4, and the median is the same. If the specific capacities of most wells in the New Oxford Formation were determined from tests of several hours' duration and at high pumping rates, they probably would not exceed 3 gpm per foot of drawdown.

The specific capacity of a well drilled in the New Oxford Formation increases as each new water-yielding zone is penetrated. It is possible, therefore, to confirm the presence or absence of water-yielding zones, and to determine the relative increases in yield supplied by different zones, by measuring the specific capacity of a well at different times as it is being deepened. In most instances satisfactory results may be obtained with a submersible pump powered by a small portable generator and capable of discharging 20 to 50 gpm. Tests at each depth should be made at approximately the same rate of discharge for the same period of time (preferably 1 hour or more), and the water level should be at or near static level prior to the start of each test. Measurements of the drawdown and discharge rate should be made as precisely as possible.

Pumping levels commonly drop below yielding zones in wells in the New Oxford Formation, even at moderate rates of discharge. When this occurs, the specific capacity of the well decreases. Once the pumping level goes below a yielding zone, the zone becomes free flowing, and any further increase in the drawdown causes an increase in yield from lower zones only. Because of this relationship, the specific capacity of a well determined at a single rate of discharge generally cannot be used to evaluate the performance of a well at different rates of discharge. The specific capacity of well Ln-88, as determined from a 1-hour test at 52 gpm, was 1.4 when the pumping level was above the two principal yielding zones. The specific capacity of the well determined from a 1-hour test at 78 gpm was 0.9 when the pumping level was below the upper

yielding zone. The lower specific capacity at the deeper pumping level can be attributed partly to the fact that the pumping level was below a yielding zone, but it may also be partly due to greater well loss at the higher pumping rate.

Effect of well loss on specific capacity — The drawdown in a pumped well includes drawdown due to well loss as well as drawdown due to aquifer loss, although the former may be negligible at low rates of discharge. Well loss is the loss in head that occurs as water enters a well and flows to the pump intake. Aquifer loss is the loss in head that results from the laminar flow of water through the formation toward the well. The sum of these two components of drawdown, s_w, in a well tapping a single, confined aquifer of uniform thickness and large areal extent, having constant coefficients of transmissibility and storage, may be represented by the following equation (Jacob, 1950, p. 372):

$$s_w = \underbrace{\frac{2.30Q}{4\,\pi\,T} \log \frac{2.25Tt}{r^2_w\ S}}_{\text{(Aquifer loss)}} + \underbrace{CQ^n}_{\text{(Well loss)}} \qquad (1)$$

where

T and S are the coefficients of transmissibility and storage as previously defined;

Q is the rate of discharge;

t is the time since pumping began;

r_w is the radius of the well;

C is a constant governed by the radius, construction, and condition of the well;

and

n is a constant greater than 1 with a theoretical upper limit of 2.

Examination of equation 1, for determining specific gravity,

$$\frac{Q}{s_w} = \frac{1}{\frac{2.30}{4\pi T} \log \frac{2.25Tt}{r^2_w\ S} + CQ^{n-1}} \qquad (2)$$

shows that specific capacity decreases as the discharge increases. However, since well loss may be very small at low rates of discharge, the change in specific capacity due to changes in low rates of discharge also may be very small. Further examination of equation 2 shows that specific capacity decreases as time increases (assuming constant discharge and no recharge), because that part of the drawdown due to aquifer loss increases as time increases. The importance of stating both the rate and the duration of discharge of a test for specific capacity is readily apparent.

Because well loss is related to well radius, the effect that enlarging the diameter of the well may have in reducing this loss is discussed in the following paragraphs.

The rate of discharge, Q, of a well may be shown as

$$Q = A\ V, \tag{3}$$

where A is the cross-sectional area of the openings through which flow occurs and V is the velocity of flow. In a well of given size, therefore, the magnitude of well loss (CQ^n) is determined by the velocity of the flow into and within the well, because so long as the water level remains above the yielding zones the area of entry into the well and the cross-sectional area of the well itself remain constant. Apparently, well loss may be reduced by reducing the velocity of flow into and within the well. This can be done by increasing the size of the well. Rewriting equation 3

$$V = \frac{Q}{A},$$

it can be seen that for any given discharge the velocity of flow is inversely proportional to the cross-sectional area of the opening through which flow occurs. Todd (1959, p. 109) discusses this relationship as follows: "It is apparent that well losses can be minimized by keeping velocities into and within wells to a minimum. In this connection the relation between well discharge and well size should be noted" * * *. "Doubling the well radius doubles the intake area, reduces entrance velocities to about half, and (if n=2) cuts the frictional loss to less than a third. For axial flow within the well, the area increases four times, reducing this loss to an even greater extent."

Well loss is believed to cause a substantial part of the drawdown, at moderate rates of discharge, in some small (6-inch-diameter) wells in the New Oxford Formation. In addition, well loss probably is significant in larger wells at high rates of discharge.

An attempt was made to measure the well loss in a 6-inch well (Ln-88) by analyzing data from a step-drawdown pumping test according to methods outlined by Jacob (1947) and Rorabaugh (1953). Both methods gave anomalous results, apparently because the hydraulic characteristics of the New Oxford Formation differ so greatly from those of the assumed ideal aquifer to which the methods apply. Nevertheless, Figure 8 shows that a marked decrease in the specific capacity occurs as the rate of discharge from well Ln-88 increases, and a sizable part of the decrease appears to be caused by well loss.

All but one of the discharge-drawdown plots in Figure 8 were determined for pumping periods of 1 hour, starting at zero drawdown. The

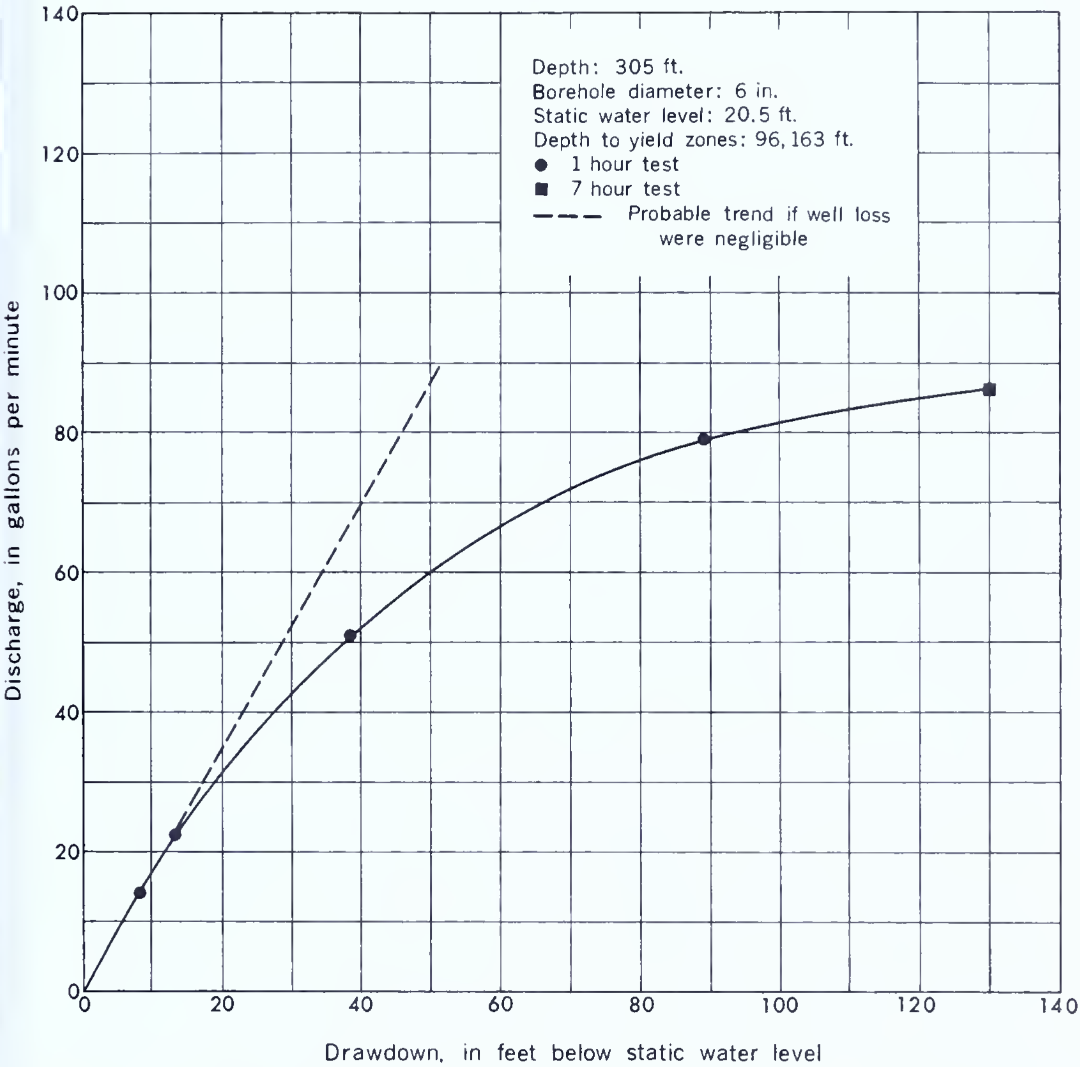


Figure 8. Graph showing the decrease in specific capacity (yield per foot of drawdown) of well Ln-88 as discharge increases.

specific capacity at 86 gpm was determined (after pumping had proceeded for 7 hours) from the second step of a step-drawdown pumping test. The pumping levels at discharges of 14, 23, and 52 gpm were above both yielding zones; at discharges of 78 and 88 gpm the pumping level dropped below the upper yielding zone. Although the decrease in specific capacity at the two higher rates of discharge can be explained partly by the fact that the pumping levels at these rates were below one of the yielding zones, the decrease in specific capacity between the discharges of 23 and 52 gpm cannot. It would appear that about one-fourth of the drawdown at 52 gpm was due to well loss, and very probably an even higher fraction of the drawdown at higher discharge rates is due to well loss.

A specific-capacity graph plotted from data obtained from tests of equal duration at different rates of discharge could be used to detect well loss in other wells in fractured rocks. If the data from three or more tests plot as a straight line (that is, if the decrease in specific capacity as the discharge increases is slight), well loss within that range of discharge may be considered negligible. However, if the data should plot as a curve that departs significantly from a straight line, well loss may be considered to cause a substantial part of the drawdown — provided that the pumping levels have not dropped below a yielding zone. If the data from several tests plot as a straight line at low discharges but depart from the straight-line trend at higher rates of discharge, the departure from the straight-line trend at any given discharge will be an approximate measure of drawdown caused by well loss.

If most of the well loss results from high entrance velocities, well-development techniques such as surging may cause the yielding zone or zones to become enlarged near the well, thus achieving the same effect as would be produced by increasing the diameter of the well by drilling. However, if the yielding zone is a thin fracture from which little or no material can be removed by well development, increasing the diameter of the well may be the only means of reducing well loss.

QUALITY OF WATER

Dissolved mineral matter in ground water is derived chiefly from the soils and rocks through which the water moves. The type and amount of dissolved material in the water are related to such factors as the mineral composition of the soils and rocks with which the water has been in contact, the length of time of contact, the solvent power of the water, and the temperature and pressure of the environment in which the water occurs. In addition, human activities such as the discharge of sewage into septic tanks or cesspools, the spreading of fertilizers and insecticides on croplands, and the burial of refuse in sanitary landfills may greatly affect the type and amount of dissolved matter that occurs in ground water.

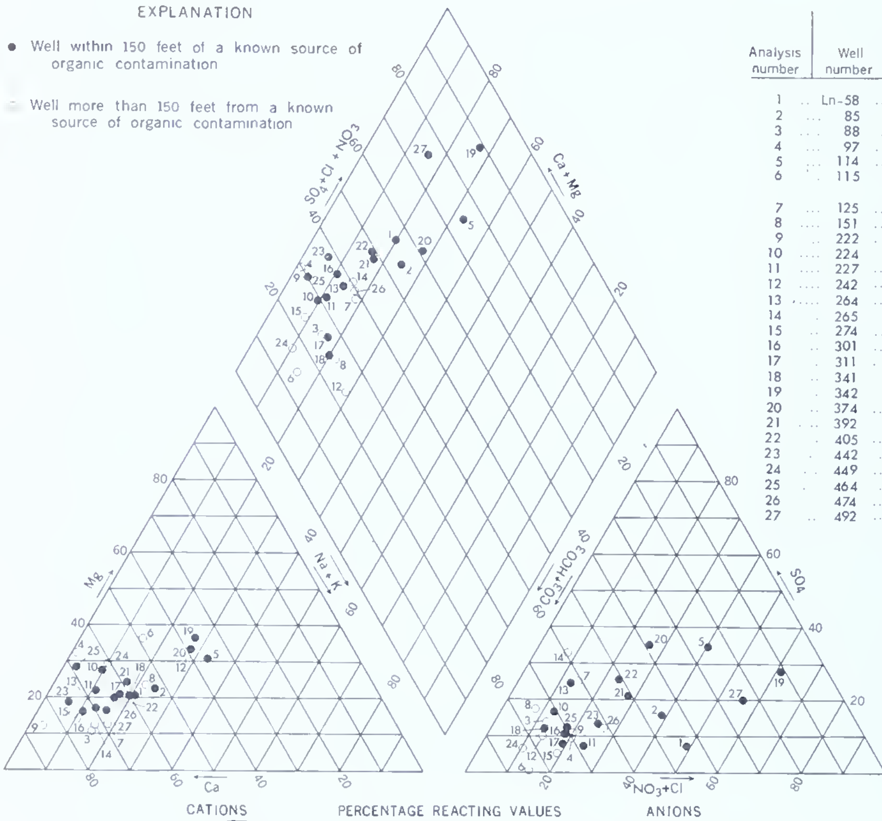
The evaluation of the quality of ground water in the New Oxford Formation presented in the following pages is based on a study of chemical analyses of water from 25 drilled wells, 1 dug well, and 1 spring. An analysis was made also of ground water from 1 well in the Gettysburg Formation. Field measurements of specific conductance and hardness were made at approximately 350 wells and springs; the pH was determined at 170, and temperature measurements were made at 85. Results of the chemical analyses, which were made by the U. S. Geological Survey, are given in Table 5. Field determination of water quality

are given together with well data in Table 4. The chemical analyses include determinations of all the major ionic constituents that normally occur in ground water. Also included in 24 of the analyses are determinations of the content of alkyl benzene sulfonate (ABS), a principal ingredient in modern household detergents.

No attempt was made to evaluate the sanitary quality of the water. It should not be assumed, however, that water of satisfactory chemical quality is also of satisfactory bacterial quality. One well that yielded water of good chemical quality was later reported by the owner to have been tested and found bacterially contaminated.

Ground water from the New Oxford Formation is of good chemical quality except where locally contaminated. The water contains low to moderate amounts of dissolved mineral matter and, with the exception of some water that may require treatment for hardness, generally is satisfactory for most purposes. Several wells were reported to be contaminated as a result of human activities, but in most instances the source of contamination is within 100 to 200 feet of the well or spring affected. The contaminants include bacteria, nitrate, iron, manganese, juices from silos, gasoline, and fuel oil. The most common source of nitrate and bacterial contaminants are effluents from septic tanks, cesspools, or cattle pens. The only known instance of ground-water contamination by iron and manganese, as a result of man's activities, is in the vicinity of sanitary landfill where these two constituents were apparently leached from the buried refuse. Gasoline and fuel-oil contamination of ground water has occurred as a result of leaks in domestic, farm, and commercial storage tanks and, in one instance, from a leak in a fuel transmission line.

Ground water in the New Oxford Formation is chiefly of the calcium bicarbonate type. However, several samples collected from wells that are near septic tanks or cesspools have an anion composition dominated by sulfate, chloride, and nitrate. The chemical character of the water has probably been altered by the addition of nitrate, chloride, and possibly some sulfate derived from the decomposition of organic wastes. The chemical character of 27 ground-water samples may be compared on the water-analysis diagram in Figure 9. Each point in the diamond-shaped field of the figure represents a single chemical analysis. The position of these points was determined by first plotting the percent emp (equivalents per million) of the cations and anions of each sample in the small triangles in the lower part of the figure. The cation and anion plots were then extrapolated to the diamond-shaped field to form a single point representing the composition of the entire sample. The analyses are segregated into two groups — those obtained from wells



Analysis number	Well number	Total dissolved solids (ppm)	Remarks
1	Ln-58	161	
2	85	131	
3	88	193	
4	97	257	
5	114	197	Bacterially contaminated.
6	115	407	Spring. Sanitary land-fill 1,000 ft. upslope.
7	125	230	
8	151	169	
9	222	288	
10	224	130	
11	227	194	Cased to 180 ft.
12	242	56	
13	264	302	
14	265	265	
15	274	186	
16	301	360	Cased to 176 ft.
17	311	158	
18	341	104	
19	342	200	
20	374	109	
21	392	205	
22	405	245	
23	442	222	
24	449	205	
25	464	199	Cased to 50 ft. Grouted.
26	474	195	
27	492	270	Cased to 70 ft.

Figure 9. Water-analysis diagram showing variations in chemical composition of ground water from the New Oxford Formation.

that are within 150 feet of a known source of organic contamination and those that are at greater distances from a known source of organic contamination. Figure 9 shows that only the water from wells near a known source of organic contamination has an anion composition dominated by sulfate, chloride, and nitrate, and that all the wells distant from a source of organic contamination yield water of the calcium bicarbonate type. The several wells that are near septic tank drain fields or cesspools, and that also yield calcium bicarbonate water, are apparently so constructed or so situated that little or no waste water reaches the well.

One of the wells (Ln-114) that yielded water of the sulfate-chloride-nitrate type was subsequently reported by the owner to be bacterially contaminated. Plot number 27 represents a sample from a drilled well in the unsewered community of Hopeland. This well is 100 feet deep and is cased to 76 feet. The owner reported that analysis had shown no evidence of bacterial contamination of the water. Nevertheless, the high-nitrate content of the water (85 ppm) indicates that the chemical character of the water is strongly affected by the large volume of sewage discharged into the ground from several nearby homes.

The fact that the character of the water from some wells has been altered by the addition of chemical substances derived from sewage or some other source of contamination does not necessarily mean that the water has been rendered unfit for use so far as its chemical composition is concerned; the concentration of substances added to the water may be well under the limits established for its intended use. It is true that domination of the anion composition by sulfate, chloride, and nitrate may indicate bacterial contamination. However, chemical contaminants travel greater distances and persist for longer periods of time than do bacterial contaminants; hence, a well may yield water high in nitrate or some other sewage-derived chemical constituent without being bacterially contaminated.

The minimum, median, and maximum concentrations of constituents present in 26 ground-water samples from the New Oxford Formation are summarized in Table 2. Data from an analysis of water from a spring (Ln-115) contaminated by sanitary landfill were not used in this summary. Included in the table are the recommended maximum limits for selected constituents in drinking water. These limits, established by the U. S. Public Health Service (1962), should not be exceeded unless other more suitable supplies are not or cannot be made available.

Nitrate is a common but generally minor constituent in most ground water and usually occurs in concentrations of less than 10 ppm. The presence of nitrate in amounts greater than this is often related to human activities. Much of the nitrate contained in the samples analyzed for this investigation is believed to have come from sewage discharged into septic tanks or cesspools near the well sampled, from fertilizers spread on croplands, or from a combination of these sources. Only 7 of 27 samples analyzed contained less than 10 ppm nitrate; the median concentration of nitrate was 21 ppm. In areas where ground-water quality is unaffected by human activities, much of the nitrate is derived from the oxidation of nitrogen present in plant debris. Another common source of naturally occurring nitrate is a group of plants known as legumes which, through bacteria on nodules on their roots, are able to take nitrogen from the air and fix it in the soil. These plants return more nitrogen to the soil than they take from it.

Many wells in unsewered communities where homes are closely spaced almost certainly yield water containing nitrate derived from sewage discharged into the ground. Well Ln-492, for example, is in the small but congested and unsewered community of Hopeland. The sample from the well contained 84 ppm nitrate, an above-average chloride concentration of 32 ppm, and an ABS content of 0.18 ppm. The high content of nitrate and chloride, both of which are major components of sewage, together with significant amounts of ABS indicate rather clearly

Table 2. Summary of chemical quality of ground water from the New Oxford Formation together with recommended limits for certain constituents in drinking water.

Constituent	Concentration in ppm except specific conductance and pH (26 samples) Minimum	Median	Maximum	Maximum concentration recommended for drinking water[a]
Silica (SiO_2)	5.2	16	28	....
Iron (Fe)	.00	.08	.39	0.3
Manganese (Mn)	.00	.01	.24	.05
Calcium (Ca)	6.0	45	90	....
Magnesium (Mg)	2.7	7.6	18	....
Sodium (Na)	.8	9.5	16	....
Potassium (K)	.0	1.1	5	....
Bicarbonate (HCO_3)	18	128	268	....
Sulfate (SO_4)	4.0	22	67	250
Chloride (Cl)	2.1	9.0	32	250
Nitrate (NO_3)	1.6	22	84	45
Fluoride (F)	.0	.0	.1	(b)
Alkyl benzene sulfonate (ABS)[c]	0.00	0.02	0.28	0.5
Total dissolved solids (sum)	56	198	360	500
Ca-Mg hardness as $CaCO_3$	26	139	274	....
Noncarbonate hardness as $CaCO_3$	1	41	124	....
Specific conductance (micromhos/cm at 25°C)	75	332	584	....
pH	5.8	7.3	7.8	....

[a] U. S. Public Health Service (1962).

[b] Recommended limits for fluoride vary according to the annual average of maximum daily air temperatures. Recommended upper limits range from 1.7 ppm in areas where the average maximum air temperature ranges between 50° and 53.7°F to 0.8 ppm in areas where it ranges between 79.3° and 90.5°F.

[c] 23 samples.

that sewage is a principal source of the nitrate. A similar relationship can be shown for well Ln-342, a shallow, uncased, dug well in Mastersonville. The sample from this well contained 73 ppm nitrate, 18 ppm chloride, and 0.18 ppm ABS. The fact that several wells in the formation are bacterially contaminated is a further indication that sewage is a source of the nitrate in their water.

Inasmuch as the project area is mostly farmland, significant quantities of nitrate in the ground water probably come from the organic and in-

organic fertilizers added to the intensively cultivated croplands. Most of the nitrate content of 26 ppm in the sample from well Ln-274, for example, may have come from fertilizers. This well is on a hilltop in the middle of a cultivated field northwest of Terre Hill and is about 600 feet upslope from the nearest source of sewage.

Serious and occasionally fatal poisonings of infants in the United States and in other countries have followed ingestion of well waters containing large quantities of nitrate. Nitrate poisoning is apparently confined to infants during their first few months of life, as adults drinking the same water are not affected. However, breast-fed infants of mothers drinking such water may be poisoned (U. S. Public Health Service, 1962, p. 48). The limit recommended by the U. S. Public Health Service for nitrate in drinking water is 45 ppm. Two of the samples analyzed for this study exceeded this limit, and both were from wells in areas of closely spaced homes serviced by septic tanks and cesspools. Many wells in such communities probably yield water containing excessive amounts of nitrate.

Alkyl benzene sulfonate (ABS) is a synthetic organic chemical used in household detergents. The presence of ABS in well water indicates that the water contains sewage-derived chemicals and may indicate that the supply is bacterially contaminated. The presence of small amounts of ABS in drinking water causes no toxic effects in humans, but concentrations of more than 0.5 ppm may cause an undesirable taste and foaming. Several of the wells sampled contained significant amounts of ABS, but none contained more than the 0.5 ppm limit recommended for drinking water.

Iron and manganese, which resemble each other in chemical behavior are generally present in ground water in small amounts. Even in trace amounts, however, these constituents have a considerable effect on the utility of the water. Individual or combined concentrations of iron and manganese in excess of 0.3 ppm cause stains on plumbing fixtures, cooking utensils, and laundry; concentrations greater than 1 ppm may cause clogging of pumps, water-distribution systems, and plumbing fixtures.

Naturally occurring iron and manganese do not appear to be present in objectionable amounts in ground water throughout most of the area underlain by the New Oxford Formation. Only one of the samples of well water contained more than 0.3 ppm. A sample of water obtained from a spring (Ln-115) contaminated by a refuse burial site, however, contained 12 ppm iron and 6.5 ppm manganese. The spring is in a draw that heads 1,000 feet upslope at the refuse burial site.

Hardness is a property of water generally associated with its effect on the lathering of soap and with incrustations formed on containers

when water is heated or evaporated. Most hardness is caused by calcium and magnesium but minor constituents such as iron, manganese, aluminum, barium, and free acid also contribute to hardness. Hardness caused by cations in association with carbonate and bicarbonate is termed carbonate hardness; that resulting from cations in association with other anions is termed noncarbonate hardness. These terms approximate the terms "temporary hardness" and "permanent hardness," which are based on the fact that upon boiling hard water the bicarbonate is decomposed and most of the calcium corresponding to the bicarbonate is precipitated as calcium carbonate. The consumption of soap by water of a given hardness is normally the same whether the hardness is carbonate or noncarbonate. The total hardness of water is equivalent to that reported as calcium-magnesium hardness. Most of the hardness of natural ground water in the New Oxford Formation is carbonate hardness.

Field determinations of hardness of water from 343 wells and springs in the New Oxford Formation are listed in Table 4. The measurements were determined in grains per gallon, but the approximate concentration in parts per million may be calculated by multiplying these values by 17.1. The hardness of the waters sampled ranged from 1 grain per gallon (17.1 ppm) to 30 grains per gallon (513 ppm), or from soft to very hard. Only 11 percent of the wells and springs sampled yielded water that could be classed as very hard. The frequency distribution of hardness values measured is shown in Figure 10. The figure also indicates concentrations of hardness that are described by the terms soft, moderately hard, hard, and very hard water.

In the area between the Susquehanna River and Denver, ground-water hardness decreases slightly from west to east. Water from wells and springs west of Mastersonville generally is moderately hard to hard; that east of Mastersonville generally is soft to moderately hard. Many of the harder waters in this area come from wells near the base of the formation, where limestone conglomerate occurs in many places. Locally, the hardness of water may be somewhat higher than normal as a result of the addition of hardness-forming constituents from septic tanks, cesspools, or other sources of contamination.

Substantial amounts of hardness-forming constituents in water cause increased consumption of soap and undesirable scale deposits on cooking utensils, hot water pipes, water heaters, and boilers. Water that is hard to very hard requires treatment before it can be used for many industrial and commercial purposes, and treatment generally is desirable when it is used for domestic purposes. Water that is moderately hard may be used for domestic purposes with little or no treatment.

The specific conductance of a material is a measure of its ability to conduct an electric current. It is the electrical conductance of a cube

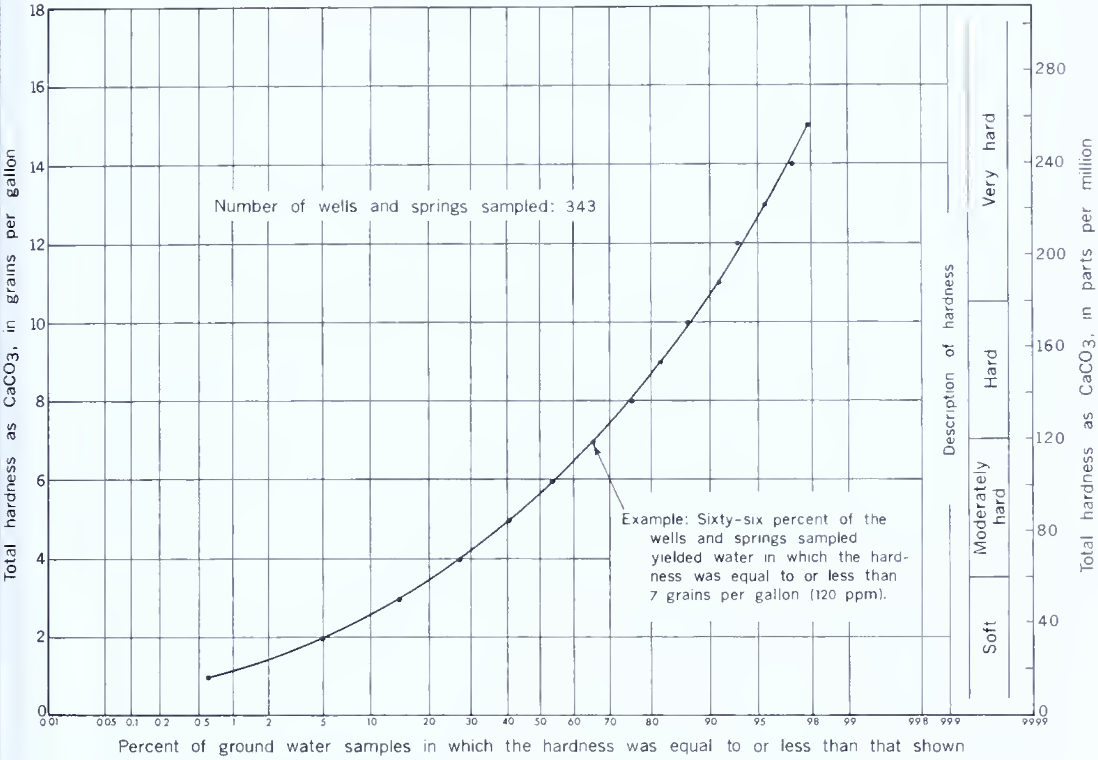


Figure 10. Cumulative-frequency curve of hardness of ground water from the New Oxford Formation.

of material 1 centimeter on a side, and is reported in units of micromhos per centimeter at a temperature of 25°C. In relatively dilute solutions, such as ground water from the New Oxford Formation, specific conductance is proportional to dissolved solids and, therefore, gives an approximate measure of total dissolved-solids content. Because specific conductance may be easily and rapidly determined in the field, the approximate dissolved-solids content of a large number of samples may be determined conveniently and inexpensively. The approximate dissolved-solids content (in parts per million) of the water from 349 wells and springs in the New Oxford Formation for which specific conductance values were determined (see Table 4) may be calculated by multiplying the specific conductance by 0.60.

The dissolved-solids content (calculated from specific conductance) of 349 samples of ground water from wells and springs in the New Oxford Formation ranged from about 35 to 725 ppm. The frequency distribution of the dissolved-solids content of these samples is shown in Figure 11, and indicates that fewer than 1 percent of the samples contained more than 500 ppm, the recommended limit for drinking water.

The dissolved-solids content of the ground water is generally higher near the base of the formation — apparently because of the presence of

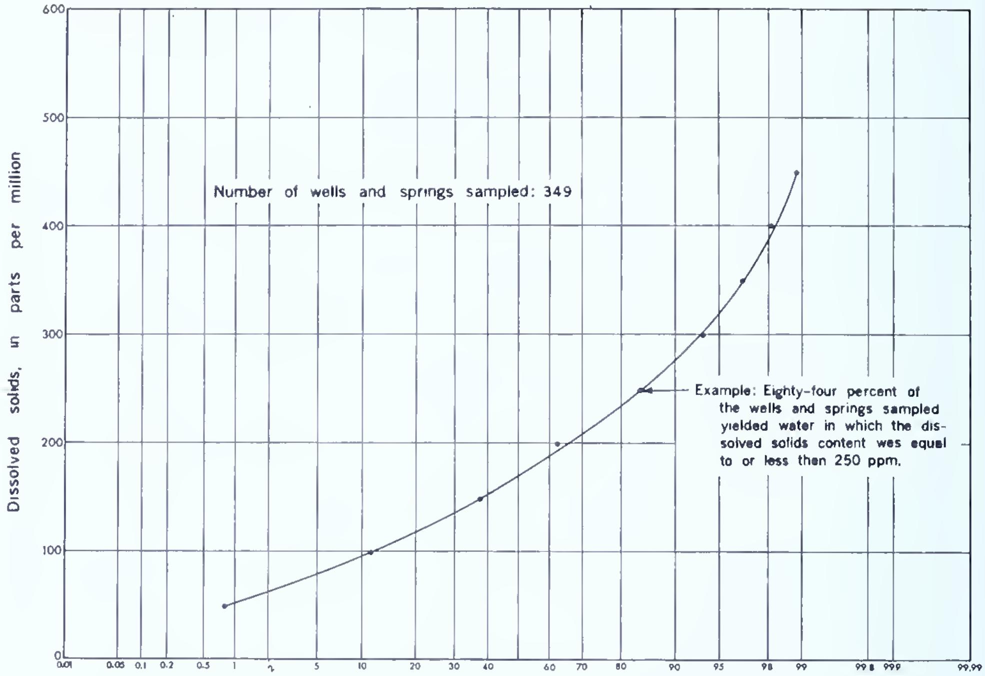


Figure 11. Cumulative-frequency curve of dissolved-solids content (calculated from specific conductance) of ground water from the New Oxford Formation.

limestone conglomerate and the many beds of limy siltstones and shale in the lower part of the formation. Locally the dissolved-solids content of ground water is high because of the addition of chemical constituents by human activities.

Ground-water temperatures in the New Oxford Formation vary over a narrow range and average about the same as the average annual air temperature. The temperature of water from 65 wells and 20 springs ranged from 49° to 60° (or 90 percent) of the measurements falling between 52° and 58° F. The average temperature of the ground water is 54.5° F; the average annual air temperature in the project area is 53° F. A comparison of ground-water temperatures from dug wells and springs with those from drilled wells showed no significant differences. The temperature from 51 drilled wells ranged from 49° to 59° F and averaged 54.4° F. The temperature of water from 34 dug wells and springs ranged from 49° to 60° F and averaged 54.6° F.

CONCLUSIONS

The New Oxford Formation is a complexly interbedded sequence of conglomerates, sandstones, siltstones, and shales that have a steep homoclinal dip (ranging from 25° to 60°) to the north or northwest. The rocks are highly indurated and generally contain water only in fractures and

in openings formed by weathering processes. The formation is deeply weathered, and contains many joints. In the eastern part of Lancaster County, it has been intensively faulted.

The bedrock is covered by a layer of loosely consolidated weathered material, which ranges in thickness from 0 to 50 feet and averages about 23 feet. The saturated thickness of the mantle, in which water occurs under water-table conditions, ranges from 0 to 24 feet and averages 6 feet. The porosity of the weathered mantle is high but its permeability is low. Consequently, it is capable of storing relatively large volumes of water but generally yields water very slowly to the large-diameter dug wells that tap it. The high storage capacity of the mantle makes it highly effective in contributing recharge to the underlying bedrock.

Within the bedrock, water occurs under confined conditions along joint surfaces and in intergranular openings formed where the walls of joints have been weathered. Sandstones (the most abundant rock type) and conglomerates, which have been more thoroughly jointed and weathered than siltstones and shales, are the principal water-yielding rocks. Some beds or parts of beds have been more intensively jointed and (or) weathered than others, and it is these beds or zones that form the main avenues for ground-water movement through the bedrock. The principal yielding zones penetrated by wells are commonly no more than a few inches thick and generally are separated by several feet or several tens of feet of rock that yields little or no water directly to the well. Individual yielding zones, like individual beds, are normally of small areal extent. The main yielding zones are hydraulically connected to each other and to the overlying water table through joints and associated weathered zones. The strike of the best developed joint sets is roughly parallel to the strike of the bedding. One prominent set dips in the direction of the bedding dip; another dips almost vertically. The intensity of weathering decreases rapidly below the bedrock surface, but thin weathered zones have been observed as deep as 150 feet. Weathering is most intense along joints in highly feldspathic rocks. In some instances weathering appears to have increased the permeability of the bedrock.

Recharge to the ground-water reservoir is derived largely from the approximately 40 inches of precipitation received by the area annually. The precipitation is distributed fairly uniformly throughout the year, but most of that falling during the growing season (April to October) is consumed by evapotranspiration. Hence, ground-water replenishment occurs chiefly during the nongrowing season (November to March). As recharge is generally low during the growing season, droughts during these periods commonly cause ground-water levels to decline only slightly below normal levels. The water level in a drilled well in the New

Oxford Formation just west of the project area showed a net decline of less than 1 foot over a 4-year period, even though precipitation during the 4 successive growing seasons ranged from 19 to 54 percent below normal. Ground-water levels are likely to be affected more adversely by relatively small precipitation deficiencies during the nongrowing seasons than by large deficiencies during the growing season.

During the growing season, when natural discharge from the ground-water reservoir exceeds recharge to it, heavy pumping from production wells may result in extensive dewatering of the weathered mantle and bedrock near the well, even where water is being diverted from natural discharge. Pumping levels and yields will decline accordingly. The yield of one municipal well, which has been pumped about 9 hours a day since 1955, declines from about 200 to 170 gpm during the growing season, and the water level in an observation well 400 feet away declines as much as 70 feet during the same period. During the winter and spring months, recharge greatly exceeds both natural and artificial discharge in the vicinity of this well. If precipitation during the winter and spring months is average or above average, the dewatered rock becomes nearly or completely refilled before the next growing season. Although yields and pumping levels of production wells commonly decline and rise with seasonal depletion and replenishment of the ground-water reservoir, none of the existing production wells are reported to be continuously decreasing in yield, and apparently ground-water levels are not persistently declining in the vicinity of these wells.

The New Oxford Formation is not everywhere a highly productive source of water, but yields of 100 to 300 gpm can be obtained from some carefully located, large-diameter wells drilled to depths of 300 to 500 feet. Yields adequate for domestic use are obtainable throughout most of the formation — usually from wells 150 feet or less in depth.

The yields of 319 wells, most of which are between 50 and 150 feet deep, range from less than 1 to 330 gpm, and the median is 12 gpm. The highest yields generally are obtained from deep wells, but there is no consistent relationship between yield and well depth. Some deep wells are failures. Yields of 14 wells deeper than 300 feet range from 7 to 330 gpm, but half of them yield 100 gpm or more. By comparison, only 6 of 146 wells between 100 and 300 feet deep yield 100 gpm or more. The maximum depth at which water occurs in the New Oxford Formation is not known, but a high-yielding zone, or zones, is known to occur between the depths of 500 and 705 feet in a municipal supply well in Elizabethtown. Water may be obtained at depths of more than 500 feet elsewhere in the formation, but it probably would be advisable to drill another well into a different sequence of rocks rather than to continue drilling an unsuccessful well to a depth greater than 500 feet.

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Table 3. Summary of specific-capacity data for wells in the New Oxford Formation in Lancaster County.

Well number	Depth of well (feet)	Diameter of casing (inches)	Depth to static water level (feet)	Discharge (gallons per minute)	Drawdown (feet)	Specific capacity (gpm per foot of drawdown)	Length of test (hours)	Date test began
Ln-55	182	6	26.4	22.3	13.1	1.7	1	11- 1-63
55	182	6	25	63	55	1.1	16	11-14-63
57	242	6	45.7	21.7	9.3	2.3	1	2-18-64
57	242	6	45.5	60	33.5	1.8	52	12-10-63
58	258	6	45.1	11.2	34	.3	1	7-31-63
81	65	6	16.1	4.9	15.6	.3	1	4- 8-63
85	318	8	23.3	7.9	11.5	.7	1	4- 8-63
88	100	6	20.4	13.2	24.1	.5	1	6-17-63
88	203	6	18.4	14.0	7.8	1.8	1	6-18-63
88	305	6	20.5	22.7	13.1	1.7	1	6-24-63
88	305	6	20.6	52	38.3	1.4	1	5-26-64
88	305	6	20.7	78	88.8	.9	1	5-28-64
88	305	6	20.6	88	145.2	.6	7	5-26-64
93	66	6	14.4	5.5	35.3	.2	.5	4- 2-63
108	100	6	15.8	11.8	51.0	.2	1	10-11-62
123	148	8	9.5	23.6	8.4	2.8	1	11- 8-63
125	500	10	35	400	115	3.4	24	9- 7-54
140	179	6	25.0	13.2	29.7	.4	1	5- 2-63
151	500	10	47	450	163	2.8	48	3- 3-58
158	105	6	11.1	12.8	11.7	1.1	1	7-31-63
178	86	6	45.7	10.9	1.9	5.8	1	10-11-62
181	99	6	24.4	3.5	11.6	.3	1	10-24-62
181	99	6	24.4	8.0	44.7	.2	1	10-24-62
183	93	6	16.2	27.1	17.1	1.6	1	5-20-63
183	93	6	16.2	26.5	21.4	1.2	24	5-20-63
183	93	6	16.2	26.3	24.1	1.1	96	5-20-63
190	379	8	12.8	23.2	4.6	5.1	1	7-12-63
214	571	10	72	63	188	.3	1	9-14-56
214	571	10	72	50	211	.2	28	9-14-56
215	339	8	45	210	20	10.5	2	7-20-51
215	339	8	45	150	141	1.1	72	7-20-51
219	82	8	26	86	12	7.2	1	8-12-59
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

222	135	10	4.1	24.2	.42	57.6	1	5- 5-64
222	135	10	5	250	18	13.9	72	1963
236	182	6	42.2	9.5	23.3	.4	1	10-19-63
238	153	6	48.7	10.1	31.1	.3	1	7-18-63
242	205	6	13.2	25.0	12.6	2.0	1	6-21-63
242	300	6	12.7	23.0	11.5	2.0	1	6-25-63
257	121	6	71.8	5.9	17.9	.3	1	5-28-63
265	500	10	55	187	193	1.0	8	1964
265	705	10	55	450	155	2.9	8	1964
267	476	10	9	115	161	.7	9	1-15-42
311	80	6	6.4	6.9	.97	7.1	1	7-30-63
318	118	6	27.3	6.9	20.5	.3	1	7-30-63
351	87	6	3.1	8.0	7.5	1.1	1	7-30-63
395	110	6	29.3	9.4	13.4	.7	1	8- 5-63
441	113	6	18.6	7.1	10.7	.7	1	8- 2-63
450	80	6	17.6	5.0	20.5	.2	1	8- 2-63
473	151	6	7	110	93	1.2	24	1950
474	252	6	12	110	108	1.0	24	1950

Table 4. Record of wells and springs and field determinations of water quality in the New Oxford Formation and adjacent rocks in Lancaster County.

Well location number: See page 6 for description of well-numbering system. Well locations are shown on plate 1.
Driller: Kohl Bros., Harrisburg, Pa. (H); Kohl Bros., Myerstown, Pa. (M).
Method of construction: Dr, drilled; Du, dug; Sp, spring.
Total depth: m, measured depth; other depths are reported.
Depth to bottom of casing: Reported.
Aquifer: Qt, terrace deposits; Trd, diabase; Trg, Gettysburg Shale; Trn, New Oxford Formation; Oc, Cocalico Shale.

Static water level: Reported depths are given in feet: measured depths are given in feet and tenths.
Reported yield: <, less than; >, greater than.
Use: C, commercial; D, domestic; I, industrial; Irr, irrigation; It, institutional; P, public supply; R. recreational, S. stock; T, U.S. Geological Survey test well; U, unused; X, destroyed.
Remarks: Ca, chemical analysis of ground water in table 5; Dd, drawdown; L, lithologic log in table 6; P, pumping-test data in table 3. Comments are based on reported information.

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
50	005-639	Guy Hoffman			Dr	6	>100		Trn			2	D						
51	005-639	do.	R. Myers' Sons, Inc.	1959	Dr		275		Trn	10- 3-62	69.6	1	U						No casing.
52	005-639	do.	do.	1959	Dr	6	160	40	Trn			6	D	10- 3-62	315	8	7.2		
53	005-639	do.			Sp				Trn				S	10- 3-62	280	7	7.0	56	Not flowing 10-3-62.
54	005-639	Pierre deVitry			Du	40	15m		Trn	10- 5-62	8.7		D						
55	005-639	Bainbridge Water Authority	R. Myers' Sons, Inc.	1963	Dr	6	182m	21	Trn	11-21-63	29.7	100	P	11-15-63	220	5		53	P.
56	005-639	do.	do.	1963	Dr	6	222m	23	Trn	11-21-63	29.2	35	U						
57	005-639	do.	do.	1963	Dr	6	242m	23	Trn	11-22-63	46.8	85	P	12-11-63	225	6		54	P.
58	005-640	Bainbridge Elementary School		1933	Dr	6	250		Trn	7-31-63	45.1	10	It	2-29-61	270	4	6.2	59	Ca, P.
59	005-640	Benjamin Myers	R. Myers' Sons, Inc.	1955	Dr.	6	115	20	Trn	9- ? -62	35		D	9-25-62	260		7.1		
60	005-640	G. C. Rhodes, Jr.	H. K. Honberger Sons		Dr	6	175	38	Trn			8	D						
61	005-640	Isaac H. Holler	R. Myers' Sons, Inc.	1954	Dr.	6	124	24	Trn	3-14-63	30.3	30	D	3-14-63	135	3	6.3		
62	005-640	Lloyd A. Rapp	do.	1959	Dr	6	93	63	Trn			50	D	3-26-63	550	13			

63	005-640	Marin Comp	H. K. Honberger Sons	1946	Dr	6	137	20	Trn	3-27-63	41.9	5	D	3-27-63	450	9	6.5		
64	006-638	David Shearer	R. Myers' Sons, Inc.	1958	Dr	6	110		Trn	6- ? -58	45	3	D	10- 5-62	275	7	6.9		
65	006-638	James Meckley			Du	48	14m		Trn	10- 5-62	9.4		D	10- 5-62	205	4	5.7	60	
66	006-638	Elmer Walters	R. Myers' Sons, Inc.	1953	Dr	6	95		Trn				D	10- 8-62	175	5	5.7		
67	006-638	B. L. Keener			Du	40	17m		Trn	10- 8-62	16.7		U						
67	006-638	do.			Dr	6	85		Trn	10- 8-62	24.8		D						
68	006-638	J. L. Meckley	R. Myers' Sons, Inc.	1962	Dr	6	167	34	Trn	8- ? -62	25	15	S	10- 8-62	250	6	7.2		
70	006-638	Raymond Nissley			Du	48	30		Trn	3- ? -59	20		U						
70	006-638	do.		1930	Dr	6	100		Trn			5	D	10- 8-62	360	7	6.5		
71	006-638	Sylvester Walters	H. K. Honberger Sons	1963	Dr	6	285	60	Trn	12- 4-63	62.0	3	D						
73	006-639	Martin Good		1942	Dr	6	90	25	Trn				D	9-28-62	250	5	6.5		
74	006-639	John K. Risser			Sp				Trn				D	9-28-62	210	4	6.4	57	Flow about 5 gpm, 9-28-62.
75	006-639	Mervin R. Miller			Sp				Trn				D, S	9-28-62	300	6	6.8	58	Flow about 5 gpm, 9-28-62.
76	006-639	Abner Risser	H. K. Honberger Sons	1955	Dr	6	57		Trn	10- ? -55	20	>10	D	9-28-62	235	4	6.0		
77	006-639	Merl J. Miller			Dr	6	120		Trn				D	10- 3-62	450	12	7.4		
78	006-639	do.			Du	36	24m		Trn	10- 3-62	16.7		U						
79	006-639	Alvin Nissley	H. K. Honberger Sons	1954	Dr	6	110m	20	Trn	10- 5-62	36.7		D	10- 5-62	335	7	6.4	55	
80	006-639	do.			Du	60	33m		Trn	10- 5-62	32.6		U						
80	006-639	do.			Dr	6	53m		Trn	10- 5-62	36.4	<3	U						Well Ln-79 is 15 feet away at same altitude.
81	006-639	Raymond Nissley	R. Myers' Sons, Inc.	1959	Dr	6	65m	23	Trn	10- 8-62	17.5	5	S	10- 8-62	355	7	6.6	54	P.
82	006-640	Rufus S. Miller		1945	Dr	6	70		Trn	9- ? -62	23	5	D, S	9-24-62	285	5	6.4		
83	006-640	do.			Du	48	41m		Trn	9-24-62	Dry		U						

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
83	006-640	do.	R. Myers' Sons, Inc.	1961	Dr	6	185	44	Trn	9-24-62	49.7	<5	D	9-24-62	275	6	7.3		
84	006-640	R. Shoop			Sp				Trn				D, S	10- 5-62	295	5	5.9	55	Flow about 5 gpm, 10-5-62
85	006-640	Natural Development Co.	Kohl Bros. (H)	1945	Dr	8	318		Trn	3- 4-63	28.2	>25	I	4- 8-63	210	4	6.3	55	Ca, P.
86	006-640	P. R. Lewis		1957	Dr	6	100	30	Trn	4- ? -57	24	>10	D	3- 3-63	180	4	6.3		
87	006-640	Henry Stauffer			Du	42	29m		Trn	4-25-63	19.8		U						
87	006-640	do.		1930	Dr	6	99m		Trn	4-25-63	29.1		D, S	4-25-63	265	6	7.4		
88	006-641	U.S. Geological Survey	C. H. Eichelberger	1963	Dr	6	305m	24	Trn	6-24-63	20.5	80	T	6-24-63	310	7	6.9	52	Ca, L, P. Most water enters at 96 and 163 ft.
89	006-641	Ebersole Bros.	H. K. Honberger Sons	1962	Dr	8	162	18	Trn	7- ? -62	7	78	I	9-25-62	500	6	6.6		Dd <140 feet after pumping 24 hours at 78 gpm.
90	006-641	Ruben O. Ebersole	Kohl Bros. (H)	1954	Dr	6	75	40	Trn			7	D	9-25-62	260	5	7.6		
91	006-641	Paul Garber	R. Myers' Sons, Inc.	1960	Dr	6	95	22	Trn			12	C	9-25-62	145	3	6.6		
92	006-641	Benjamin Burkholder			Du	40	23m		Qt	3-11-63	19.6		D	3-11-63	325	6	6.9	49	
93	006-641	do.	R. Myers' Sons, Inc.		Dr	6	65m		Trn	4- 2-63	12.7	1	D	4- 2-63	325	7	6.9	55	P.
94	006-641	do.	do.		Dr	6	<100		Trn	4- 6-63	13.6	3	D	4- 6-63	290	8	6.9	52	
95	006-641	C. Rodney Fink	do.	1961	Dr	6	100	33	Trn	4- ? -61	18	5	D						
96	007-634	Rheems Water Co.	H. K. Honberger Sons	1912	Dr	10	120		Trn			50	P	11- 7-62	425	11	7.7	54	
97	007-635	Heisey Bros.	do.	1962	Dr	6	102m	23	Trn	10-17-62	21.1	40	D	10-17-62	470	10	7.1		Ca. Dd <45 feet after pumping 20 days at 40 gpm.
98	007-635	Ray E. Helwig	R. Myers' Sons, Inc.	1955	Dr	6	118		Trn				D	10-17-62	360	8	7.1		

99	007-635	Amos Gentz	Honberger Sons	[illegible]	Dr	6	[illegible]		[illegible]										
100	007-635	Robert Tormo	R. Myers' Sons, Inc.	1962	Dr	6	123	21	Trn	7- ? -62	20	3	D	10-23-62	280	6	6.7		
101	007-635	do.			Du	60	18m		Trn	10-23-62	14.6		U						
102	007-635	Ruth Williams	R. Myers' Sons, Inc.	1962	Dr	6	95	21	Trn			20	D	10-23-62	270	6	7.5		Most water enters at 95 feet.
103	007-635	Harry Foreman		1927	Dr	6	142		Trn			3	D						
104	007-635	do.	R. Myers' Sons, Inc.	1957	Dr	6	252	21	Trn	11- 2-62	69.5	40	I	11- 2-62	415	10	7.3		Dd 60 feet after bailing 2 hours at 40 gpm.
105	007-635	Robert S. Mason	H. K. Honberger Sons	1945	Dr	6	200		Trn			>10	D	11-30-62	285	7			
106	007-635	James S. Beamenderfer	do.	1950	Dr	6	87	21	Trn	5-31-63	23.1	4	D	5-31-63	360	10	6.9	52	
107	007-635	John Wanger	R. Myers' Sons, Inc.	1963	Dr	6	202	22	Trn			6	D						
108	007-636	R. E. Keller	do.	1962	Dr	6	100	39	Trn	10-11-62	14.8	15	D	10-11-62	230	6	6.6	54	P.
109	007-636	Robert H. Chapman	H. K. Honberger Sons	1952	Dr	6	72		Trn	6- ? -52	40	20	D	10-15-62	125	2	6.1		
110	007-636	Samuel Snyder	do.	1959	Dr	6	175		Trn	9- ? -59	25	5	D	10-16-62	315	8	7.2		Most water enters at 130 feet.
111	007-636	do.			Sp				Trn				U	10-16-62	260	5	5.9	58	Flow <5 gpm. on 10-16-62.
112	007-636	Ammon Snyder	R. Myers' Sons, Inc.	1931	Dr	6	150		Trn				D	10-17-62	510	10	6.9		
113	007-636	I. H. Ober			Sp				Trn				D	10-17-62	125	3	6.4	58	Flow about 5 gpm on 10-17-62.
114	007-636	Warren D. Nauman	Samuel R. Kaylor	1956	Dr	6	85		Trn			20	D	10-17-62	205	4	6.1		Ca.
115	007-636	Masonic Homes			Sp				Trn				U	4-30-63	535		6.5	49	Ca. Flow about 15 gpm. on 4-30-63.
116	007-637	Richard Stone	Kohl Bros. (H)	1946	Dr	6	65	15	Trn	9- ? -46	6	7	D	10- 9-62	285	6	6.3		
117	007-637	Raymond Appley	do.	1948	Dr	6	90		Trn			15	D	10- 9-62	220	5	6.6		
118	007-637	Earl Kreider	R. Myers' Sons, Inc.	1959	Dr	6	122	29	Trd			3	D	10- 9-62	215	5	6.3		
119	007-637	Earl M. Heisey	do.	1960	Dr	6	80	29	Trn	2- ? -62	15	10	D	10-12-62	230	4	5.6		
120	007-637	Earl M. Heisey			Du	48	18m		Trn	10-12-62	17.3		U						

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
122	007-637	Mahlon H. Fry			Sp				Trn				D, S	10-23-62	125	2	6.4	57	Flow about 10 gpm, 10-23-62.
123	007-637	Masonic Homes			Dr	8	148m		Trn				U	10- 4-63	285	7		58	P.
124	007-637	do.			Dr	10	200		Trn			110	It	5-31-63	350	7	6.6	55	
125	007-637	do.	Kohl Bros. (H)	1954	Dr	10	500	33	Trn	9- 7-54	35	330	It	5-17-63	380	8	7.2	56	Ca. P. Casing grouted in 12-inch hole.
126	007-638	Elvin H. Nolt			Dr	6	125		Trn				D	10- 9-62	425	9	6.9		
127	007-638	do.			Du	48	30m		Trn	10- 9-62	24.3		U						
128	007-638	Earl Heisey			Sp				Trn				D, S	10-12-62	205	4	5.6	58	Flow averages <10 gpm.
129	007-638	Leroy Martin			Du	40	33m		Trn	9-17-63	30.6		U						
130	007-639	A. Retherford			Dr	6	70m		Trn	9-28-62	25.3		D, S	9-28-62	425		6.6		
131	007-639	Walter E. Ebersole	E. Gerlach and Sons, Inc.	1952	Dr	6	89		Trn	10- ? -52	25		D	10- 8-62	125	2	6.0		
132	007-639	Norman L. Zeager			Sp				Trn				U	10- 9-62	155	3	5.9	55	Flow <5 gpm on 10-9-62.
133	007-639	Walter Ebersole	R. Myers' Sons, Inc.	1958	Dr	6	76		Trn				D	10- 8-60	260	5	5.2		
134	007-640	Andrew Stoner			Du	60	20m		Trn	9-26-62	18.2		D	9-26-62	155	6	6.1		
135	007-640	Samuel H. Retherford			Dr	6	114		Trn				D	9-28-62	300	4	6.0		
136	007-640	do.			Dr	48	28m		Trn	9-28-62	26.8		U						
137	007-640	do.	R. Myers' Sons, Inc.	1963	Dr	6	110		Trn			8	D	12-11-63	155	2			
138	007-640	Norman L. Zeagler, Jr.	do.	1958	Dr	6	200		Trn	12-11-63	38.7	12	D	12-11-63	220	4			

139	007-641	Ebersole Bros.	Honberger Sons	1959	Dr	6	102	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							
140	007-641	Vernon Zimmerman	R. Myers' Sons, Inc.	1963	Dr	6	179m	35	Trn	4-26-63	34.1	30	D, S	5- 2-63	250	6	7.3	55	P. Most water enters below 175 feet.
141	008-633	R E. Garman	do.	1951	Dr	0	123	73	Trn	5- ? -51	45	12	D	10-15-62	335	8	7.6		Dd. about 70 feet after bailing ½ hour at 5 gpm.
142	008-633	Kenneth H. Eshleman			Dr	6	100		Trn			>5	D, S	10-15-62	515	12	6.7		
143	008-633	do.			Du	48	31m		Trn	10-15-62	23.5		U	10-15-62	600	13	7.2	57	
144	008-633	Reist R. Mummau	R. Myers' Sons, Inc.	1962	Dr	6	165	21	Trn			25	D	0-13-63	240	7	6.7		
145	008-634	Milton D. Sechrist	do.	1961	Dr	6	110	21	Trn			4	D	10-15-62	305	9	7.0		
146	008-634	Elizabeth Longenecker	do.	1959	Dr	6	103	25	Trn			10	D						
147	008-634	Charles W. Pfaunmiller			Du	40	20m		Trn	10-29-62	19.1		D	10-29-62	140	2	6.0		
148	008-634	J. Pfaunmiller	R. Myers' Sons, Inc.	1962	Dr	6	95	21	Trn			6	D						
149	008-634	Norman S. Good			Du	36	24m		Trn	6-13-63	21.3		D	6-13-63	205	4	5.9	52	
150	008-634	Gerald Sager	R. Myers' Sons, Inc.	1962	Dr	6	96	39	Trn			12	D	6-13-63	360	8	6.1		
151	008-635	Elizabethtown Water Co.	Kohl Bros. (II)	1958	Dr	10	500	51	Trn	3- 3-58	47	300	P	7-19-63	270	8	7.1		Ca, P. Pumping level varies between 150 and 180 feet.
152	008-635	Robert H. Smith	R. Myers' Sons, Inc.	1956	Dr	6	112	21	Trn			20	C	10-26-62	410	10	7.1		Most water enters at 60 and 90 feet.
153	008-635	R. E. Hershey	H. K. Honberger Sons	1952	Dr	6	75	30	Trn	11- 7-62	59.0	<5	U						Yield was 16 gpm, when well was drilled.
154	008-635	do.	R. Myers' Sons, Inc.	1957	Dr	6	240	80	Trn			9	C	10-29-62	290	6	6.8		
155	008-635	Paris Good	do.	1951	Dr	6	130		Trn	10-29-62	>55.0		D	11- 1 -62	410	8	7.5		
156	008-635	do.			Du	48	30m		Trn	10-29-62	29.8		U						
157	008-635	Charles H. Simon	Kohl Bros. (II)	1942	Dr	8	505		Trn	3- ? -49	60	120	U	11- 1 -62	250	5	6.7	54	Dd about 100 feet after pumping 24 hours at 120 gpm.
158	008-635	do.	H. K. Honberger Sons	1941	Dr	6	108		Trn	11- 1-62	10.1	18	U	7-31-63	180			54	P.
159	008-635	Sadie Risser	R. Myers' Sons, Inc.	1961	Dr	6	100	22	Trn	11- 2-62	39.1	20	D	11- 2 -62	300	6	7.1		
160	008-635	Rheems Water Co.			Dr	6	300		Trn			10	U						

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
161	008-635	do.			Dr	10	300		Trn			10	U	12-2-62	220	5	6.2	54	
162	008-635				Dr	6	300		Trn			10	U						
163	008-635	Rheems Water Co.		1954	Dr	6	200	20	Trn			10	P	10-9-63	340	8		54	
164	008-635	do.			Dr	6	300	20	Trn			10	U						
165	008-635	J. M. Smith	R. Myers' Sons, Inc.	1959	Dr	6	330	37	Trn			7	D	11-30-62	215	4			
166	008-635	Charles H. Simon			Dr	6	120		Trn			40	D						
167	008-635	Acme Market	R. Myers' Sons, Inc.	1959	Dr	6	300	20	Trn	5-?-63	2	25	U						
168	008-635	do.	do.	1959	Dr	6	300	20	Trn	5-?-63	2	25	U						
169	008-635	do.	do.	1959	Dr	6	300	20	Trn			10	U						
170	008-635	Longenecker Hatchery		1910	Dr	6	60		Trn			2	U						
171	008-635	do.	R. Myers' Sons, Inc.	1950	Dr	6	60	25	Trn			5	U						Yield dropped from 18 to 5 gpm in 1955.
172	008-635	do.	do.		Dr	6	130	25	Trn	4-5-63	49.9	30	S						
173	008-635	Longenecker Hatchery	R. Myers' Sons, Inc.	1960	Dr	6	130	25	Trn	1-?-60	50	30	S						
174	008-635	Harold Martin	do.	1963	Dr	6	175	22	Trn			20	D	6-10-63	350	9	6.7		
175	008-635	do.		1954	Dr	6	95m		Trn	6-10-63	70.2	10	U						
178	008-636	West Donegal Township	R. Myers' Sons, Inc.	1962	Dr	6	86m	23	Trn	10-10-62	45.8	50	D	10-11-62	400	9	6.0	54	P. Most water enters below 60 feet.
179	008-636	Philip P. Metzger	do.	1960	Dr	6	65	21	Trn	6-?-61	2	10	D	10-12-62	365	9	7.5		

180	008-636	do.	do.	1962	Dr	6	65	30	Trn	7- ? -62	6	15	D	10-12-62	435	11	7.2		
181	008-636	Henry Decker	H. K. Honberger Sons	1962	Dr	6	99m	54	Trn	10-12-62	23.4	7	D	10-24-62	290	6	6.7	55	P. Water enters from sandstone diabase contact at 88 feet.
182	008-636	Clyde Carter	do.	1961	Dr	6	75	59	Trn	9- ? -61	19	20	D	10-12-62	375	9	6.5		Water enters at 70 feet.
183	008-636	Willowood Swim Club	do.	1956	Dr	6	93	35	Trn	11- 1-62	18.8	30	R	5- 2-63	300	6	6.6	54	P.
184	008-636	Paul Moyer		..	Sp				Trn				D, S	11-13-62	300	5	6.0	54	Flow <5 gpm on 10-13-63.
185	008-636	Daniel Reem	H. K. Honberger Sons	.	Dr	6	120	58	Trd		30	12	D						
186	008-636	Masonic Homes		1920	Dr	8	100		Trn	5-15-63	25.7		U						
187	008-636	do.		1924	Dr	10	306		Trn			110	U						
188	008-636	Klein Chocolate Co.	R. Myers' Sons, Inc.		Dr		500		Trn			40	I	5- 5-63				57	Yield was 70-100 gpm in 1935.
189	008-636	do.	do.		Dr		230		Trn			140	I						Yield was 200 gpm when drilled.
190	008-636	Ebersole Ice and Coal Co.	do.	1945	Dr	8	379m		Trn	7-12-63	12.8	100	U	7-12-63	365	8			P.
191	008-636	Paul H. Kauffman			Dr	6	183m		Trn	5-27-63	4.7		D	5-27-63	320	8	6.8		
192	009-601	Paul R. Weaver	R. Myers' Sons, Inc.	1955	Dr	6	50		Trn				D	4-20-64	240	5			
193	009-603	Isaac Zimmerman			Dr	6	108		Trn				D, S	4-16-64	425	7			
194	009-604	R. M. Weaver	Titus Sensenig	1960	Dr	6	60		Trn		Flows	25	D	4-16-64	450	10		58	
195	009-604	Lester Martin	do.		Dr	6	65		Trn		10	12	D	4-16-64	390	9		54	
196	009-604	Susanna Herr			Du	60	20m		Trn	5-13-64	13.7		D	5-13-64	320	7			
197	009-605	Horace Styer	Norman Zimmerman	1949	Dr	6	93	20	Trn		35		D	4-15-64		5			Most water enters between 90 and 93 feet.
198	009-605	Ivan Stauffer	R. Myers' Sons, Inc.		Dr	6	50		Trn			>15	D	4-20-64	230	7			
199	009-608	Irvin H. Nolt	do.	1957	Dr	6	86		Trn		20	12	D, S	4-15-64	360	9			
200	009-609	Ephrata Sand and Gravel	H. K. Honberger Sons	1959	Dr	6	175m	20	Trn	4-10-64	17.2	55	I						Dd <100 feet after pumping 14 days at 55 gpm
201	009-609	do.	do.	1959	Dr	6	140m		Trn	4-10-64	20.8		U						

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
202	009-609	David Oberholtzer	Titus Sensenig	1962	Dr	6	128	42	Trn			>30	P	4-10-64	415	12			Most water enters at 110 feet.
203	009-609	Aaron Burkholder			Dr	6	30		Trn			10	D, S	4-15-64	485	11			
204	009-609	do.			Du	60	26m		Trn	4-15-64	10.3		U						Fuel oil in water 4-15-64.
205	009-609	Edgar H. Martin	R. Myers' Sons, Inc.	1961	Dr	6	118	55	Trn	8- ? -61	4	4	D	4-15-64	380	13			
206	009-609	D. B. Stauffer	A. W. Martin	1950	Dr	6	296	70	Trn	1- ? -51	55	<1	D	4-15-64	345	11			
207	009-609	do.	do.	1951	Dr	6	100	25	Trn	1- ? -51	18	>30	D, S	4-15-64	325	7		49	
208	009-609	Justin Andrew	E. Cerlach and Sons, Inc.	1964	Dr	6	122	67	Trn			12	D						
209	009-610	Harold Brossman			Dr	6	27m		Trn	4-12-64	7.6	10	D	4-12-64	345	11			
210	009-610	M. W. Brossman	R. Myers' Sons, Inc.	1959	Dr	6	78	25	Trn			13	D	4-12-64	280	8			
211	009-611	Raymond C. Sweigert		1929	Dr	6	60		Trn		12	>10	D	4- 7-64	510	16			
212	009-611	Jonas Groff	Titus Sensenig	1957	Dr	6	98	40	Trn				D, S	4- 7-64	650	21			
213	009-611	Christian Sauder	do.	1962	Dr	6	80	40	Trn		30	>25	D	4- 7-64	400	12			
214	009-611	Borough of Akron	Kohl Bros. (H)	1956	Dr	10	571	52	Trn	9-18-56	72	50	P	4- 9-64	405	14			P. Water enters at 30, 75, 90, 220 and 335 feet.
215	009-611	do.	Paul C. Myers	1951	Dr	8	339	63	Trn	7- ? -51	45	150	P						P.
216	009-611	do.			Dr	10	136m		Trn	4- 9-64	76.1	20	U						
217	009-611	do.			Dr		>200		Oc			<1	X						
218	009-611	do.			Dr	8	>100		Oc			18	U						

219	009-611	do.	H. K. Honberger Sons	1959	Dr	8	82	62	Trn	8-15-59	26	185	P	4- 9-64	435	15			P.
220	009-611	do.	R. Myers' Sons, Inc.	1951	Dr	10	64	13	Oc	4- ? -64	Flowing	>20	U						
221	009-611	do.	do.	1963	Dr	6	126m		Trn	4- 9-64	11.0	250	U	5- 5-64	585	19	7.3	53	P. Water enters at 58 and 116 feet.
222	009-611	do.	do.	1963	Dr	10	135m	38	Trn	4- 9-64	5.56	250	U	5- 5-64	490	13	7.3	53	Ca. P. Most water enters below 100 feet.
223	009-611	Raymond Knosp	do.	1964	Dr	6	65	35	Trn	4- ? -64	21	10	D						
224	009-630	Richard McCoy		1950	Dr	6	74m	28	Trn	10-18-63	20.9	>10	D	5-13-64	235	6	6.9		Ca.
225	009-631	Franklin Greiner		1944	Dr	6	85		Trn		19		D, S	6- 7-63	500	14	6.9		
226	009-631	James Ginder	R. Myers' Sons, Inc.	1961	Dr	6	88	84	Trn	4- ? -61	25	20	D, S	6- 7-63	400	9	6.5		
227	009-632	Charles Bitner	H. K. Honberger Sons	1950	Dr	6	185	180	Trn		80	10	D	6- 7-63	315	8	6.5		Ca. Depth (85 feet) and casing (30 feet) increase to eliminate gasoline.
228	009-632	Ralph Ginder			Dr	6	149		Trn				D, S	6-13-63	380	11			
229	009-632	do.	R. Myers' Sons, Inc.	1961	Dr	6	230		Trn	6-26-63	26.9	2	U						
230	009-632	Blaine Gantz	do.	1962	Dr	6	200		Trn			11	D, S	6-27-63	390	11	6.9		
231	009-632	do.			Du	40	17m		Trn	6-27-63	11.6		U	6-27-63	170	4	6.6		
232	009-632	Victor Ginder			Du	40	31m		Trn	6-27-63	29.2								
232	009-632	do.			Dr	6	122m		Trn	6-27-63	29.4		D	6-27-63	250	5	6.2		
234	009-632	Ralph G. Herr	R. Myers' Sons, Inc.	1946	Dr	6	94	21	Trn	4- ? -64	15		D, S	6-27-63	185	5	6.3		
235	009-632	William Thome	do.	1961	Dr	6	80		Trn	7-15-63	26.8	12	S	10-22-63	285	6	7.6		Most water enters at 65 feet.
236	009-632	do.	do.	1963	Dr	6	182	15	Trn	10-23-63	42.2	20	S	10-23-63	300	6	7.6	55	P. Most water enters from limestone conglomerate at 177 feet.
237	009-632	Lloyd S. Hummer		1947	Dr	6	130		Trn			<5	D	7-16-63	285	8	6.8		
238	009-632	Loy Trostle	H. K. Honberger Sons	1963	Dr	6	153m		Trn			12	S	7-18-63	125	3	6.1	54	P. Water enters at 96 and 150 feet.
239	009-633	Harry J. Beck			Dr	6	110	60	Trn			20	D	5-23-63	85	2	5.7		
240	009-633	Arthur Koser	R. Myers' Sons, Inc.	1962	Dr	6	185	25	Trn	6-13-63	9.6	6	D	6-13-63	385	11	6.7		

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
241	009-633	Irvin Ruhl			Du	36	20		Trn		15		D	6-13-63	220	5	5.9	53	
242	009-633	U.S. Geol. Survey	C. H. Eichelberger	1963	Dr	6	300m	39	Trn	6-25-63	11.8	110	T	6-25-63	90	2	5.8	53	Ca, P.
243	009-633	Raymond Newgard	R. Myers' Sons, Inc.		Dr	6	170	70	Trn	6-26-63	55.9	25	D						
244	009-633	Edward Snavely			Dr	6	103		Trn	6-20-63	48.5		D	6-20-63	170	3	6.0		
245	009-633	West Greentree Church of the Brethren			Du	40	47m		Trn	6-27-63	42.2		It	6-27-63	120		5.7		
246	009-634	Robert Zeigler	R. Myers' Sons, Inc.	1962	Dr		123m	23	Trd	10-26-21	83.1	10	D						
247	009-634	Willis H. Hackman			Sp				Trn				D, S	10-29-62	260	4	5.8	56	Flow about 5 gpm on 10-29-62.
249	009-634	Guido Clauss	R. Myers' Sons, Inc.	1956	Dr	6	106	80	Trn	11-13-62	11.3	12	D, S	11-13-62	195	4	6.5		
250	009-634	do.			Du	36	19m		Trn	11-13-62	8.7		U						
251	009-634	Abram E. Musser			Dr	6	34m		Trn	11-13-62	7.5	8	S	11-13-62	355	7	6.4		
252	009-634	do.			Du	36	40m		Trn	11-13-62	15.9		D						
253	009-634	Baum's Bologna Co.	H. K. Honberger Sons	1961	Dr	6	198	80	Trn	2- ? -61	15	60	1	11-14-62	325	7	7.3		Cased off 12 gpm. All water enters below 165 feet.
254	009-634	do.			Dr	6	154	20	Trn	11-14-62	12.2		U						
255	009-634	Moyer's Potato Chip Co.			Dr	6	87		Trn	11-15-62	30.6	15	I	11-16-62	330	5	6.8		
256	009-634	do.			Du	48	32m		Trn	11-16-62	27.1		U						
257	009-634	Russel Eisenbise	R. Myers' Sons, Inc.	1963	Dr	6	121m	24	Trn	5-21-63	70.5	10	D	5-28-63	270	6	6.4	54	P.
258	009-635	John D. Reinhold	......	1952	Dr	6	90	......	Trn	9- ? -52	3	>10	D	10-29-62	270	6	6.9		

259	009-635	Ray Swanger	....	....	Du	48	24m		Trn	11-14-62	18.7		D	11-14-62	415	7	6.2	....	....
260	009-635	Paul K. Zook	R. Myers' Sons, Inc.	1956	Dr	6	60		Trn	9- ? -56	12	20	D	11-14-62	300	7	7.3		
261	009-635	Chester Landis	do.	1952	Dr	6	110		Trn	11-15-62	11.9	>10	D	11-15-62	225	5	5.8		
262	009-635	do.			Du	36	14m		Trn	11-15-62	10.0		U	11-15-62	345	7	6.4	55	
263	009-635	John Chapman	R. Myers' Sons, Inc.	1961	Dr	6	65	20	Trn	9- ? -61	10	7	D	12- 4-63	415	8			
264	009-635	Lester Hess	do.	1964	Dr	6	80	22	Trn	4- 1-64	21	15	D, S	5- 1-64	490	12	7.6		Ca.
265	009-636	Elizabethtown Water Co.	Kohl Bros. (H)	1954	Dr	10	705	24	Trn	4-29-54	55	180	P	2-27-61	415	10	7.3		Ca, L, P. Major yielding zone below 500 feet.
266	009-636	do.		1915	Dr	8	205m		Trn				U						See Fig. 6 for hydrograph.
267	009-636	do.	Kohl Bros. (H)	1942	Dr	10	476	20	Trn	4- ? -42	9	115	U						P. Has flowed during wet spring.
268	009-636	do.			Dr	6	220		Trn				U						Has flowed during wet spring.
269	009-636	do.			Dr	8	168m		Trn				U						
270	009-636	Mumpers Dairy, Inc.	R. Myers' Sons, Inc.	1950	Dr	8	330	50	Trn	11-20-63	39.4	30	C	11-20-63	405	9			Most water enters below 290 ft.
271	009-636	do.	do.	1932	Dr	6	165	20	Trn			10	C	11-20-63	450	9			
272	009-637	Aaron Hollinger		1924	Dr	6	100	20	Trn		40	10	D, S						
273	010-604	Lloyd Martin	Titus Sensenig	1961	Dr	6	90	30	Trn		30	>30	D, S	5-14-64	245	6			
274	010-604	Walter M. Martin	do.	1957	Dr	6	140	20	Trn	5-14-64	38.4	20	D, S	5-14-64	315	8	7.7		Ca. Most water enters at 140 feet.
275	010-605	E. S. Zimmerman	do.	1963	Dr	6	90		Trn				D,S	4-15-64	240	3		58	
276	010-605	Richard Kern	do.	1962	Dr	6	95	45	Trn	3- ? -62	10	45	D	4-20-64	300	8			
277	010-606	C. H. Zimmerman	A. W. Martin	1961	Dr	6	112	30	Trn		8		D	4-15-64	220	3		57	
278	010-606	Harvey O. Martin	R. Myers' Sons, Inc.	1960	Dr	6	128	40	Trn		15	20	D	4-15-64	210	4		56	
279	010-606	Lemon Werntz	R. Myers' Sons, Inc.	1963	Dr	6	80	33	Trn	12- ? -63	4		D	4-20-04	245	6			
280	010-607	M. Brubacker			Dr	6	75	25	Trn				D	4-15-64	300	6		54	

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
281	010-607	H. Kofroth	R. Myers' Sons, Inc.	1963	Dr	6	102	23	Trn	6-26-63	30	7	D	4-16-64	260	4		54	
282	010-607	Paul Fox	A. W. Martin		Dr	6	100		Trn	4-16-64	10.1		D	4-16-64	180	2		52	
283	010-607	A. W. Martin	do.		Dr	6			Trn				D	4-15-64	560	13		58	
284	010-607	Martin H. Weaver	do.	1963	Dr	6	127	44	Trn	6- ? -63	13	15	D, S	4-20-64	495	11			Dd about 70 feet after pumping 24 hrs. at 15 gpm.
285	010-607	Wayne Zeist	Titus Sensenig	1955	Dr	6	69	25	Trn	10- ? -55	8	30	D	4-20-64	300	7			Dd about 4 feet after bailing 1 hr. at 15 gpm.
286	010-607	Harvey M. Zimmerman	A. W. Martin	1959	Dr	6	150	25	Trn	7- ? -59	40	30	D	5-13-64	370	10			Most water enters at 100 feet.
287	010-608	Leroy Sensenig	do.	1948	Dr	6	154	>30	Trn	6- ? -48	20	>20	D	4-16-64	90	3			
288	010-608	Spring Glenn Farm Kitchen			Sp				Trn				I	4-16-64	125	3		52	Flow about 60 gpm on 4-16-44.
289	010-608	Francis C. Riddle			Dr	6	75		Trn				D	4-16-64	465	14			
290	010-608	Harvey Stauffer			Dr	6	76		Trn				D	4-16-64	285	8			
291	010-608	Samuel H. Gehr	A. W. Martin	1955	Dr	6			Trn			>20	D	4-16-64	220	7			
292	010-608	William Bauman	Titus Sensenig	1964	Dr	6	87	38	Trn	4-16-64	28.7	>20	D	4-16-64	570				Most water enters at 75 feet.
293	010-608	John L. Weber	R. Myers' Sons, Inc.	1963	Dr	6	60	20	Trn			20	D	4-16-64	290	8			
295	010-608	Eva Wingenroth		1944	Dr	6	110		Trn			>10	D	5-16-64	60	1			
296	010-608	Ivan S. Horst	R. Myers' Sons, Inc	1963	Dr	6	82	40	Trn		20	10	D	5-16-64	295	7			
297	010-609	Earl W. Hagy	A. W. Martin	1940	Dr	6	107	55	Trn			>15	C						
298	010-609	Arthur Sell	do.	1962	Dr	6	60		Trn			20	D	4-15-64	125	4			

299	010-609	Donald Nelson, Jr.	R. Myers' Sons, Inc.	1962	Dr	6	100	25	Trn	4-16-64	58.5	6	D	4-16-64	100	3			
300	010-609	Lester Carpenter	A. W. Martin	1964	Dr	6	148	40	Trn	4-16-64	67.1	10	D						Most water enters at 100 and 140 feet.
301	010-610	Eugene Leaman	do.	1954	Dr	6	186	170	Trn			>15	C	4-10-64	570	20			Ca. Most water enters at 184 feet.
302	010-610	Frand Livengood		1959	Dr	6	83		Trn			25	D	4-12-64	225	7			
303	010-611	George Mohler	R. Myers' Sons, Inc.	1964	Dr	6	65	35	Trn	4-12-64	24.4	10	D	4-12-64	425	14		50	
304	010-629	Jack Bowersox	do.	1959	Dr	6	104	25	Trn			3	D	8- 8-63	350	10			
305	010-629	Jacob S. Shaffer	R. Myers' Sons, Inc.	1955	Dr	6	107		Trn	4- ? -55	1	>20	D	8- 9-63	305	8			
306	010-630	Roy Ginder			Sp				Trn				D, S	7-15-63	180	3		53	Flow about 10 gpm on 7-15-63.
307	010-630	Chiquies Church	R. Myers' Sons, Inc.	1957	Dr	6	128		Trn			4	It						
308	010-630	John S. Ginder	do.	1960	Dr	6	95		Trn	8- 9-63	11.3	4	D	8- 9-63	210	4			
309	010-630	Levin A. J. Loose	do.	1963	Dr	6	130		Trn	8- 9-63	14.6	15	S	8- 9-63	235	6			
310	010-631	David Heistand	do.		Dr	6	108	50	Trn			>20	D	7-15-63	330	8			
311	010-631	Willis Christ	do.	1962	Dr	6	80	16	Trn	7-24-63	4.4	>30	D, S	5-18-64	250	7	7.1		Ca, P.
312	010-631	Galen Shenk		1959	Dr	6	86		Trn			25	D	7-23-63	385	9	6.9		
313	010-631	Milton Grove Sand Co.	H. K. Honberger Sons	1958	Dr	6	115		Trn			>10	I						
314	010-632	Alvin Risser			Du	40	25		Trn				D	6-26-63	340	8	6.7		
315	010-632	Rissers Church			Du	40			Trn				It	6-26-63	275	6	5.9	53	
316	010-632	John K. Martin			Du	40	32m		Trn	6-27-63	28.2		D, S	6-27-63	205	4	5.5		
317	010-632	Gerald Neidig			Du		37m		Trn	7-17-63	24.8		D						
317	010-632	do.			Dr		75		Trn				D	7-17-63	350	6	5.9	54	
318	010-632	Robert Hostetter	Samuel Kaylor	1959	Dr	6	118	18	Trn	7-19-63	30.1	30	D, S	7-19-63	450	11	6.6	57	P. Most water enters at 118 ft.
319	010-633	Dean Koppenhaver	R. Myers' Sons, Inc.	1957	Dr	6	127	16	Trn	6-11-57	10	12	D	7- 1-63	235	6	7.0		

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
320	010-633	Raymond Longenecker			Dr	6	58m		Trn	7-15-63	31.5		U						Gasoline odor on 7-15-63. Buried gasoline tank 50 feet away leaked Dec. 1960.
321	010-633	do.	B. Myers' Sons, Inc.	1961	Dr	6	125	44	Trn				D, S	7-15-63	290	7			
322	010-633	Lloyd S. Hummer	H. K. Honberger Sons		Dr	6	90		Trn			9	S	7-17-63	365	9	6.8		
323	010-634	Jonathan Smith, Jr.	do.	1961	Dr	6	90	27	Trn	2- ? -61	8	15	D						
324	010-634	Paul Brubaker	do.	1958	Dr	6	100		Trn	11-16-62	25.4		D	11-16-62	260	5	6.9		
325	010-634	C. S. Hollinger	do.	1958	Dr	6	95	21	Trn	11-16-62	23.9	7	D	11-16-63	255	5	7.3		
326	010-634	C. H. Smith	do.	1960	Dr	6	<150		Trn				D	11-16-62	235	5	6.2		
327	010-634	Bruce Halk	do.	1962	Dr	6	120	23	Trn	10- ? -62	25	6	D						
328	010-634	Mrs. Ralph Mummert	H. K. Honberger Sons	1961	Dr	6	90	21	Trn			15	D	11-16-62	900	21	6.9		
329	010-634	Albert J. Muchan	do.	1961	Dr	6	75	21	Trn	2- ? -61	5	10	D	1- 3-63	1,225	30	7.7		
330	010-634	Ralph Greenly		1959	Dr	6	77	20	Trn		4	7	D	11-14-62	400	8	7.1		
331	010-634	Charles Rife	H. K. Honberger	1960	Dr	6	109	19	Trn	4- ? -60	12	4	D	6-10-63	220	3	5.9		
332	010-634	Paul M. Hess			Sp				Trn				D, S	7-15-63	175	3		54	Flow about 5 gpm on 7-15-63.
333	010-635	Mrs. Mark Berrier			Du	40	32m		Trn	11-14-62	12.2		D	11-14-62	180	5	6.0		
334	010-635	Paul Wideler			Sp				Trn				D, S	11-15-62	190	3	6.4	54	Flow about 5 gpm on 11-15-62.
335	010-635	Samuel Myers		1944	Dr	6	80		Trn			5	D	11-15-62	600	14	6.6		
336	011-605	John Slaback			Dr	6	120	40	Trn		28		D	4-16-64	375	7		57	

337	011-605	Richard D. Nelson			Dr	6	80		Trn			30	D	5-13-64	380	9			
338	011-606	Eva Gehman	A. W. Martin	1964	Dr	6	90		Trn	4-15-64	2.4		D						
339	011-606	Martin Herr	Titus Sensenig	1956	Dr	6	65		Trn		8		D	4-15-64	375	10			
340	011-606	G. R. Weaver	do.		Dr	6	103	50	Trn		18		D	4-15-64	550	10		58	
341	011-606	Elwood Lees			Dr	6	40	25	Trn		Flows	>10	D	5-16-64	175	4	6.7		Ca.
342	011-629	Robert Hess			Du	48	17m		Trn	5- 7-63	11.0		D	5- 7-63	350	7	5.7	52	Ca.
343	011-629	William W. Brosey			Dr	6	120		Trn		24	>5	D	5- 7-63	485	7	6.4		
344	011-629	Raymond Shelly	H. K. Honberger Sons	1948	Dr	6	95	22	Trn			4	D	5- 8-63	420	10	6.5		
345	011-629	Elmer Shelly	R. Myers' Sons, Inc.	1960	Dr	6	90		Trn	5- ? -63	23		D	5- 8-63	165	4	6.0		
346	011-629	H. E. Grube	do.		Dr	6	63	24	Trn	5-10-63	19.1	3	D	5-10-63	385	11	6.5		
347	011-629	Henry Gingrich	do.	1955	Dr	6	110	25	Trn	8- 9-63	17.4	15	U						
348	011-629	do.	do.	1956	Dr	6	104	54	Trn	8- 9-63	49.7		D	8- 9-63	225	6			Ln-347 is 60 feet away at about 3 feet lower altitude.
349	011-629	Paul Wolgemuth	do.	1964	Dr	6	102	46	Trn	5- 1-64	27.8	8	D						
350	011-630	Eugene Shenk	do.	1962	Dr	6	110	90	Trn	9- ? -62	15	12	D, S	7-25-63	200	4			
351	011-630	Elam Ginder	H. K. Honberger Sons	1961	Dr	6	87		Trn	7-30-63	3.1	>20	D	7-29-63	160	3		55	P.
352	011-630	Roy Hess	R. Myers' Sons, Inc.	1959	Dr	6	100	20	Trn			12	D, S						
353	011-630	B. S. Hollinger			Du	40	15m		Trn	8- 9-63	13.1		D	8- 9-63	170	4			
354	001-631	Lloyd Weidman		1950	Dr	6	93	30	Trn	12- ? -50	12	>25	D	7-15-63	315	7			Most water enters at 90 feet.
355	001-631	Omer Hostetter	R. Myers' Sons, Inc.	1961	Dr	6	95		Trn			8	D, S	7-23-63	185	3	5.6		
356	011-631	do.			Du	40	52m		Trn	7-24-63	41.8		U						
357	011-631	John Wolgemuth	R. Myers' Sons, Inc.	1954	Dr	6	100	21	Trn	7-23-63	12.6	>30	D, S	7-23-63	315	7	6.8		
358	011-631	do.			Du	40	11m		Trn	7-23-63	7.5		D, S	7-23-63	220	4			Ln-357 is 120 feet away at same altitude.

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
359	011-631	Elizabeth Thompson	R. Myers' Sons, Inc.	1963	Dr	6	93	24	Trn	4-28-63	15	9	D	7-24-63	195	4	6.2		
360	011-631	Samuel S. Ginder	do.	1957	Dr	6	115	21	Trn	7- ? -57	6	>20	D, S	7-24-63	295	7	6.8		Most water enters below 100 feet.
361	011-631	do.			Du	40	26m		Trn	7-24-63	15.1		D						
362	011-631	Dale Kreiner			Dr	6	64		Trn	7-24-63	14.5	<5	D	7-24-63	240	6	7.0		
363	011-631	Raymond Miller			Dr	6	44	20	Trn	7-24-63	20.8	>15	D, S	7-24-63	220	5	5.7		
364	011-632	William B. Saylor			Du	40	16m		Trn	7-17-63	10.5		D, S	7-17-63	160	3	5.7	54	
365	011-632	Jacob Forry			Du	40	28m		Trn	7-19-63	10.2		U						
366	011-632	Paul Good			Du	40	23m		Trn	7-19-63	Dry								
366	011-632	do.			Dr		63m		Trn			<3	D, S	7-19-63	415	9	5.9		No casing.
367	012-622	Carl W. Nestleroth			Du	60	70		Trn	11-27-63	55		D, S	11-27-63	530	12			Stream 90 feet from well is at 10 feet lower altitude.
368	012-623	Aaron G. Galbreath		1929	Du	48	29m		Trn	11-14-63	23.6		U						
368	012-623	do.			Dr	6	117		Trn				D, S	11-14-63	410	6			
369	012-623	Percy Tshudy, Jr.			Dr	6	<100		Trn				D	11-14-63	375	9			
370	012-623	Mahlon Ober	Samuel Kaylor	1957	Dr	6	122	70	Trn	7- ? -57	30	>20	D	11-14-63	230	4			
371	012-624	Carl E. Martin	R. Myers' Sons, Inc.	1956	Dr	6	87		Trn	11-12-63	21.7	2	D, S	11-12-63	450	9			
372	012-624	Elmer Fahnestock	do.	1956	Dr	6	110		Trn			30	D, S	11-13-63	460	9			
373	012-624	Glen Barnes	do.	1962	Dr	6	125	28	Trn	11-14-63	19.6		D	11-13-63	150	3			Kerosene spilled 5 feet from well March 1963. Tasted in water since August 1963.

374	012-625	Rufus Waltz	do.	1948	Dr	6	82	20	Trn	....		6	D	3- 1-61	175	6	5.8		Ca.
375	012-625	Willoughby Kline			Du	40	11m		Trn	11-12-63	9.2		U						
375	012-625	do.		1948	Dr	6	200		Trn			>20	D, S	11-12-63	660	14			
376	012-625	do.			Dr	6	200		Trn		. . .	>20	D						
377	012-625	Lloyd A. Wolf			Du	40	7m		Trn	11-13-63	2.4		D, S	11-13-63	410	7			
378	012-625	Raymond Ebersole			Dr	6	77m		Trn	11-13-63	50.5		D, S	11-13-63	340	6			
379	012-625	do.			Du	48	18m		Trn	11-13-63	8.9		U	11-13-63	1,000			55	Ln-378 is 100 feet away at about 7 feet higher altitude.
380	012-626	Carl Miller			Dr	6	70	20	Trn	10-15-63	41.2		D	10-15-63	200	3			
381	012-626	Kenneth Hoffer			Dr	6	100		Trn			<10	D, S	10-22-63	255	4			
382	012-626	Samuel Wanner			Dr	6	65		Trn	4- ? -61	5		D, S	10-22-63	340	5			
383	012-626	William F. Hornberger, Sr.			Du	60	57m		Trn	10-22-63	Dry								
383	012-626	do.			Dr	6	120		Trn	10-22-63	>57.2	<5	D,S	10-22-63	405	9			
384	012-626	Jacob Byers			Dr	6	82m		Trn	11-12-63	5.7		U						
385	012-626	J. Harold Balmer	R. Myers' Sons, Inc.	1956	Dr	6	119		Trn	11-12-63	21.9	5	D, S	11-12-63	280	6			
386	012-627	Wilbur Weaver	do.	1955	Dr	6	227		Trn			4	D	10- 8-63	485	10			
387	012-627	Silas Long			Du	40	30m		Trn	10-15-63	Dry		U						
387	012-627	do.			Dr	6	80	35	Trn			20	D, S	10-15-63	715	14			
388	012-627	Paul Geib	H. K. Hornberger Sons	1953	Dr	6	76m		Trn	10-15-63	19.3		D	10-14-63	350	4			
389	012-627	John Potts	do.	1959	Dr	6	110	30	Trn	4- ? -60	30	8	D	10-15-63	155	4			
390	012-628	Myrl L. Jefferies			Du	48	25m		Trn	8- 7-63	23.7		D						
391	012-629	Raymond P. Groft	R. Myers' Sons, Inc.	1954	Dr	6	112	22	Trn			>30	D	10- 8-63	650	11			
392	012-629	Abram Siegrist	do.	1962	Dr	6	87	14	Trn	7- ? -63	8	35	Irr	5- 1-64	245	7	6.7	51	Ca. Yield 15 gpm in Aug. 1963 after pumping 4 months.

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
393	012-629	do.	do.	1956	Dr	6	75	20	Trn	5-10-63	22.0	7	D	5-10-63	315	8	6.5		
394	012-629	do.			Du	40	19m		Trn	5-10-63	11.5		U					50	
395	012-629	J. Harlan Shelly	R. Myers' Sons, Inc.	1963	Dr	6	110	23	Trn	8- 5-63	28.8	10	D	8- 5-63	265	6		56	P.
396	012-629	Paul Webber	do.	1950	Dr	6	119	20	Trn	4- ? -50	6	20	D	8- 5-63	275	7			Most water enters at 117 ft.
397	012-629	Clayton Hess	do.	1963	Dr	6	102	22	Trn	5- ? -63	17	30	D						Yielded 20 gpm between 45 and 55 feet.
398	012-629	Robert E. Suydan			Dr	6	55m		Trn	8- 7-63	20.1		D	8- 7-63	60	2		52	
399	012-629	Aaron Whitcomb			Dr	6	100		Trn			<5	D	10-11-63	225	5			
400	012-630	Homer Ginder	R. Myers' Sons, Inc.	1955	Dr	6	62	21	Trn	11- ? -55	20	12	D, S	7-25-63	265	5			
401	012-630	Roy Hess	do.		Dr	6	122	20	Trn			12	D, S	7-25-63	425	9			
402	012-630	Katie F. Shenk	do.	1962	Dr	6	88	21	Trn			12	D, S	7-25-63	700	18	6.8		
403	012-630	George Greiner	do.		Dr	6	127		Trn				D, S	7-25-63	350	8			
404	012-630	Abner Hollinger	do.	1962	Dr	6	102		Trn			10	D	7-29-63	185	4			
405	012-630	Edwin A. Moore	H. K. Honberger Sons	1963	Dr	6	122	27	Trn			8	D	8- 5-63	410	9			Ca.
406	012-631	John Ebersole	R. Myers' Sons, Inc.	1953	Dr	6	131	16	Trn	7-25-63	22.9	25	D, S	7-25-63	280	5			
407	012-632	James R. Hostetter			Du	60	43m		Trg	5-18-64	16.7		D	5-18-64	230	5			
408	013-605	Marcus Martin			Du	40	24m		Trd	4-27-64	4.2		U						
408	013-605	do.	Titus Sensenig	1958	Dr	6	86m	28	Trd	4-27-64	9.1	7	D, S	4-27-64	400	14			

409	013-605	Cedar Crest Motel			Dr	6	142m		Trn	4-27-64	48.2		C	4-27-64	410	[illegible]			
410	013-605	do.	R. D. Grant		Dr	6	100	48	Trn	1- 2-58	25	10	C						Dd about 50 feet when bailed at 10 gpm.
411	013-605	Adam Hahn	do.	1956	Dr	6	115	22	Trn	4-27-56	35	10	C	4-27-64	435	13			Dd about 55 feet when bailed at 10 gpm.
412	013-605	Howard Johnston's Restaurant	do.	1958	Dr	6	200	31	Trg	7-31-58	38	94	C						Dd 40 feet after pumping 12 hours at 94 gpm.
413	013-606	Daniel H. Martin	A. W. Martin	1958	Dr	6	90		Trn			>30	D, S	4-27-64	340	8			
414	013-606	James Shober, Sr.	R. D. Grant	1959	Dr	6	68		Trn	10- ? -59	15	15	D, S	4-27-64	195				
415	013-606	R. D. Grant	do.	1955	Dr	6	66	32	Trn			32	D						
416	013-615	Evangelical United Brethren Church	do.	1962	Dr	6	94m	40	Trn	6-15-63	4.6	10	R	6-15-63	245	6	7.1	51	Dd about 78 feet when bailed at 10 gpm.
417	013-616	Max Elser Jr. Estate	R. Myers' Sons, Inc.	1953	Dr	6	137	40	Trn	7- ? -53	20	>20	D, S						
418	013-616	Raymond Fidler		1935	Dr	6	95	40	Trn			>20	D	12- 9-63	370	7			Most water enters at 75 feet.
419	013-618	Helen Hinkle	A. W. Martin	1956	Dr	6	97		Trn				D	12- 6 63	220	5			
420	013-618	Ammon Hammer	R. Myers' Sons, Inc.	1956	Dr	6	66	25	Trn	12- 9-63	19.3	30	D	12- 9-63	90	1			
421	013-619	Donald Steffy		1952	Dr	6	190		Trn	4- ? -63	8		D, S	12- 6-63	225	4			
422	013-619	C. Robert Snader	R. Myers' Sons, Inc.	1952	Dr	6	92		Trn			4	D						
423	013-619	do.	do.	1954	Dr	6	94	21	Trn			3	D						
424	013-620	Galen Eberley			Du	48	12m		Trn	12- 5-63	8.6		D, S	12- 5-63	280	4			
425	013-620	Amos Sauder			Du	48	30		Trn	4- ? -63	24		D	12- 5-63	270	4			
426	013-620	L. W. Greenfield			Dr	6	150		Trn				D	12- 5-63	215	4			
427	013-620	Charles G. Keller			Dr	6	160		Trn	12- 6-63	20		S	12- 6-63	365	6			
428	013-621	Richard Decker		1957	Dr	6	75		Trn				D	11-27-63	215	4			
429	013-621	Mervin W. Heisey			Du	36	13m		Trn	12- 5-63	9.8		D	12- 5-63	365	6			
430	013-621	Alvin Martin			Dr	6			Trn				D, S	12- 5-63	800	15			

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
431	013-621	Walter Schreiner			Du	48	25m		Trn	12- 5-63	11.0		D, S	12- 5-63	400	8			
432	013-621	Carl R. Hess	R. Myers' Sons, Inc.	1954	Dr	6	75	20	Trn			6	S	12- 5-63	320	5			
433	013-622	John Oberholtzer	do.	1962	Dr	6	120	21	Trn			20	D	11-27-63	165	3			
434	013-622	Elwood Bradley			Dr	6	<50		Trn				S	11-27-63	255	4		55	
435	013-622	Roy Groff	Samuel Kaylor	1963	Dr	6	31	30	Trn			30	D, S	11-27-63	420	5			
436	013-623	Rufus Fahnestock	do.	1958	Dr	6	55	20	Trn			5	D, S	11-27-63	225	4			Gasoline in well 11-27-63 from buried tank 150 feet away.
437	013-623	George H. Haldeman	do.	1961	Dr	6	60	40	Trn	1- ? -61	30	8	D	11-27-63	105	2			
438	013-623	do.			Du	60	25m		Trn	11-27-63	25.3		U						
439	013-623	Wayne Shenberger		1962	Dr	6	100		Trn				D	11-27-63	275	5			
440	013-623	Harry I. Miller	Samuel Kaylor	1958	Dr	6	125		Trn			8	D	11-27-63	340	6			
441	013-624	Paul Heagy			Du	48	17m		Trn	5-23-63	11.3		S						
441	013-624	do.			Dr	6	113m	30	Trn	5-23-63	15.5	>15	S	5-23-63	425	9	6.5	56	P.
442	013-624	Roman Mosaic Tile Co., Inc.	Kohl Bros. (M)	1957	Dr	6	157	31	Trn	5- 2-57	25	25	I	5-24-63	400	10	6.9		Ca. Dd about 45 feet when bailed at 25 gpm.
443	013-625	O. N. McGee	R. Myers' Sons, Inc.	1958	Dr	6	210		Trn			>16	D	10-22-63	350	7			Most water enters near bottom.
444	013-625	Mark Wolgemuth			Dr	6	87		Trn	11-13-63	9.9		D	11-13-63	280	5			
445	013-625	Earnest Weaver	Samuel Kaylor	1959	Dr	6	70	62	Trn	11-13-63	9.2	65	D, S	11-13-63	290	5			
446	013-625	Harvey W. Weaver	....	..	Dr	6	85	.	Trn			15	D, S	11-14-63	220	3			

447	013-625	Roy Gordon	R. Myers' Sons, Inc.	1959	Dr	6	65	40	Trn	6- ? -59	10	9	D	11-14-63	300	6	....	....	....
448	013-625	Cleve Montgomery		1964	Dr	6	136		Trn			15	D						
449	013-625	Edwin Eby	R. Myers' Sons, Inc.	1964	Dr	6	110m	32	Trn	5- 4-64	22.3	6	D	5- 4-64	380	10	7.7	54	Ca.
450	013-626	Harry Leipold	do.	1960	Dr	6	80	21	Trn	5-24-63	21.5	10	D	5-24-64	320	8	6.9	56	P.
451	013-626	Charles Buchy			S				Trn				D	10-22-63	95	2			Flow about 1 gpm on 10-22-63.
452	013-626	W. L. Moyer			Du	48	23m		Trn	10-22-63	17.9		D	10-22-63	200	3			
453	013-628	John W. Fry			Du	40	19m		Trn	10-14-63	18.6		D	10-14-63	140	2			
454	013-628	United Zion Church			Dr	6	110		Trg			>10	R	3- 1-61	125	1	6.9		
455	013-630	Trinity Lutheran Church			Dr	6	100		Trg	8- 8-63	16.9	10	It	8- 8-63	240	6		54	P.
456	014-608	Chester Steuber	R. D. Grant	1963	Dr	6	95	42	Trn	11- ? -63	40	6	D	3-27-64	220	4			
457	014-608	Harry Rosehoro	do.	1964	Dr	6	89	60	Trn	3-27-64	18.6	20	D						Dd 22 feet after bailing ½ hr. at 20 gpm.
458	014-608	Eugene Trostle	do.	1962	Dr	6	80	20	Trn	7- ? -62	18	>30	D, S	4- 7-64	450	12			Most water enters from sandstone at 50 and 70 feet.
459	014-609	Ralph S. Hain, Sr.			Du	36	19m		Trn	3-27-64	14.0		D	3-27-61	230	4			
460	014-609	Mrs. Lewis Yingst			Du	60	23m		Trn	3-27-64	16.6		D	3-27-64	120	3			
461	014-609	I. E. Stauffer	A. W. Martin	1956	Dr	6	137	13	Trn	4- ? -56	8	10	D	4- 7-64	265	9			Most water enters at 137 feet.
462	014-609	Paul Schell	R. D. Grant	1960	Dr	6	102	69	Trn	4- 7-64	18.4	10	D	4- 7-64	195	5			
463	014-610	W. W. Gerhart	do.	1950	Dr	6	64	27	Trn			>20	D	3-25-64	380	10			
464	014-610	Shoeneck Elementary School	Kohl Bros. (M)		Dr	6	140	50	Trn	6-17-55	45	40	It	3-26-64	350	10			Ca. 10-in. hole to 50 feet; grouted with cement.
465	014-610	Lester Pannebecker		1945	Dr	6	100	20	Trn		....	>20	D	3-26-64	250	5			Most water enters at 95 feet.
466	014-610	Robert Brehn	R. Myers' Sons, Inc.		Dr	6	65		Trn			8	D	3-27-64	220	4			
467	014-610	Rufus Bollinger	do.	1959	Dr	6	144	60	Trn	3-27-64	20.7	3	D	3-27-64	290	5			
468	014-610	Paul Dinger	R. D. Grant	1952	Dr	5	85	32	Trn	7- ? -63	20	24	D	3-27-64	155	3			Dd about 20 feet after bailing ½ hr. at 24 gpm.

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
469	014-610	Elmer Yost	do.	1962	Dr	6	100	84	Trn	6- ? -62	55	20	D	3-27-64	510	11			Dd about 30 feet after baling ½ hr. at 20 gpm.
470	014-610	Frank Unser	do.	1963	Dr	6	117	80	Trn	12- 4-63	50	30	D						Dd about 10 feet after bailing ½ hr. at 30 gpm.
471	014-611	Mahlon Eberly	do.	1956	Dr	6	68	43	Trn	4- ? -56	25	9	D	3-24-64	275	6			
472	014-611	Harvey Eberly			Du		18		Trn										
472	014-611	do.	R. D. Grant	1949	Dr	6	71	24	Trn			>20	D, S						
473	014-611	Gulf Oil Corp.	Kohl Bros. (H)	1950	Dr	6	151	47	Trn	7-11-50	7	110	C	3-24-64	290	6			P., Dd 93 feet after pumping 24 hrs. at 110 gpm.
474	014-611	do.	do.	1950	Dr	6	252	36	Trn	3-24-64	15.0	110	C	3-24-64	345	7			P., Ca. Dd 110 feet after pumping 24 hrs. at 110 gpm.
475	014-611	Charles A. Wealand	R. D. Grant	1949	Dr	6	90	40	Trn	3-25-64	16.0	>20	D	3-25-64	220	5			
476	014-611	Levi Eberly		1960	Dr	6	65	58	Trn			7	D	3-26-64	185	4			
477	014-611	Walter Sweigert	R. D. Grant	1959	Dr	6	63	49	Trn	6- ? -59	18	20	C						Dd about 30 feet after bailing ½ hr. at 20 gpm.
478	014-612	Perry Copenhaver	do.	1959	Dr	6	68m	55	Trn	3-24-64	7.7	9	D	3-24-64	225	5		52	
479	014-612	Clyde Burkholder			Dr	6	<100		Trn	3-24-64	15.9	60	D	3-24-64	160	3			
480	014-612	Robert Loose			Du	60	25m		Trn	3-25-64	17.0								
480	014-612	do.			Dr	6	71m		Trn	3-25-64	17.0		D	3-25-64	205	4			
481	014-612	Ralph Wingenroth			Du		17m		Trn	3-25-64	10.4		D, S	3-25-64	495	8			
482	014-612	John F. Martin		1945	Dr	6	40	16	Trn		Flows	>35	D	3-25-64	360	6			
483	014-613	Walter Henly			Du	36	34m		Trn	3-23-64	21.0		U						

484	014-613	Clayton Zimmerman	Titus Sensenig	1960	Dr	6	67	66	Trn	3-23-64	6.0	>20	D	3-23-64	240	5			
485	014-613	A. N. Onemus			Dr	6	50		Trn				D	3-24-64	255	6			
486	014-614	Stephen Grosteffon	R. Myers' Sons, Inc.	1963	Dr	6	65	35	Trn			12	D	12-10-63	145	2			
487	014-614	Dean Grosteffon	do.	1959	Dr	6	50	17	Trn	12-10-63	6.0	9	D	12-10-63	180	2			
488	014-614	Daniel E. Wenger	do.	1963	Dr	6	170	21	Trn			2	D	3-23-64	155	3			
489	014-614	Cilbert Paul			Dr	6	50		Trn				D, S	3-23-64	240	5			
490	014-615	Ralph Bingeman		1920	Dr	6	80		Trn			10	U						Gasoline in well Mar. 1964. In well since tank 60 feet away leaked in Feb. 1963.
491	014-615	Howard Farlow			Du	40	13m		Trn	6- 6-63	8.7		D	6- 6-63	440		5.5		
492	014-616	James Steininger	R. Myers' Sons, Inc.	1961	Dr	6	100	76	Trn	11- ? -61	38	15	D	6- 6-63	475	11	6.1		Ca.
493	014-615	William Womer		1957	Dr	6	59	27	Trn	7- ? -61	41	10	D	12-10-63	350	8			
494	014-615	Leon Martin	R. Myers' Sons, Inc.	1963	Dr	6	93	51	Trn	7- ? -63	30	20	D	12-10-63	150	3			
495	014-615	Earl F. Smoker	R. D. Grant	1957	Dr	6	92	16	Trn	10- ? -57	20	>30	D, S	12-10-63	440	7			Most water enters at 92 feet.
496	014-615	Maurice Carter		1958	Dr	6	82	30	Trn			30	D	12-10-63	305	5			
497	014-615	Grant Schwendemann		1950	Dr	6	100	4	Trn		30	8	D	3-23-64	355	6			
498	014-615	Irvin Leisey	R. Myers' Sons, Inc.	1952	Dr	6	<100		Trn			7	D	3-27-64	475	11			
499	014-615	Ephrata Diamond Spring Water Co.	do.	1962	Dr	6	170	54	Trg			28	C						
500	014-616	Fred Wiegand	H. K. Honberger Sons	1961	Dr	6	82	52	Trn	12- ? -61	18	25	D	5-27-63	160	3	6.1		
501	014-616	Vernon Bucher	do.	1962	Dr	6	135	25	Trn	10-17-62	41	7	D	5-27-63	220	6	6.5		
502	014-616	Lloyd Miller	do.	1962	Dr	6	218	25	Trn	5-27-63	42.1	5	D						Water enters at 180 feet.
503	014-616	Jacob Borry			Sp				Trn				D, S	6- 6-63	215	5	6.1	52	Flow about 3 gpm on 6-6-63.
504	014-616	J. D. Miller			Du	48	38m		Trn	12- 9-63	32.0		D	12- 9-63	155	2			

Table 4. Record of wells and springs—Continued

Well number	Location number	Owner	Driller	Date completed	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer	Static water level: Date measured	Static water level: Depth below land surface (feet)	Reported yield (gpm)	Use	Field determinations of water quality: Date sampled	Specific conductance (micromhos at 25°C)	Hardness as $CaCO_3$ (grains per gallon)	pH	Temperature (°F)	Remarks
505	014-616	George W. Carvell		1958	Dr	6	85	35	Trn	10- ? -58	30	6	D	12- 9-63	160	3			
506	014-617	C. D. Coleman Estate			Du	40	19m		Trn	6- 6-63	11.9		D	6- 6-63	395	7	6.1	51	
507	014-617	do.	R. Myers' Sons, Inc.	1961	Dr	6	200		Trn			30	D	12- 9-63	290	5			
508	014-619	W. J. Packard	H. K. Honberger Sons	1960	Dr	6	75	62	Trn	8-15-63	4	>15	D	12- 6-63	115	2			
509	014-619	James D. Snader	do.	1960	Dr	6	128		Trg	12- 9-63	65.8	12	D	12- 9-63	155	3			
510	014-619	J. R. Ruhl	do.	1960	Dr	6	90		Trg			5	D	12- 9-63	215	5			
511	014-620	A. M. Yoder		1938	Dr	6	96		Trg				D	3- 1-61	225	4	6.3		Ca.
512	014-620	Avid Sherpf		1956	Dr	6	100	30	Trg	10- ? -56	15	25	D	12- 5-63	85	2			Most water enters at 100 feet.
513	014-620	Robert Claus		1953	Dr	6	235		Trg			<5	D						

Table 5. Summary of chemical analyses of ground water in the New Oxford formation.

[Results in parts per million except as indicated]

Well or spring number	Date of collection	Depth of well (feet)	Temperature °F	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Alkyl benzene sulfonate	Sum of dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos 25°C)	pH	Color
Lancaster County																							
Ln- 58	2-27-61	200	......	21	0.05	0.03	27	5.8	10	0.8	0	62	8.2	16	0.1	42	......	161	92	41	251	6.2	1
85	3- 4-63	318	......	19	.18	.09	20	5.4	9.6	1.0	0	52	14	9.4	.0	27	0.11	131	72	30	213	6.2	2
88	6- 4-63	305	53.5	16	.12	.12	48	4.4	11	1.2	0	152	22	14	.1	1.6	.02	193	138	14	331	7.0	5
97	5- 1-64	102	53	5.8	.0	.00	61	18	.8	.0	0	200	22	8.6	.0	42	.02	257	226	62	441	7.5	4
114	1-31-63	85	......	16	.19	.08	9.6	4.9	9.0	1.5	0	19	21	7.4	.0	18	.28	97	44	29	156	5.8	3
a115	4-30-63	......	49	17	12	6.5	76	34	14	1.5	0	384	.0	39	.0	2.4	.00	407	330	15	794	6.7	50+
125	5-17-63	500	56	17	.08	.00	52	6.0	15	.8	0	140	45	11	.0	14	.09	230	154	40	358	7.7	2
151	7-19-63	500	......	21	.14	.03	30	7.8	13	1.1	0	130	24	6.0	.1	2.0	.02	169	107	1	269	7.6	5
222	5- 5-64	135	53	7.3	.00	.01	84	7.4	3.5	.0	0	215	26	9.8	.0	44	.01	288	240	64	478	7.7	4
224	5-13-64	74	......	11	.06	.00	27	7.3	4.0	1.2	0	94	18	2.9	.0	12	.01	130	98	21	219	7.1	3
227	6- 7-63	185	......	17	.15	.00	42	8.5	7.2	1.5	0	132	12	9.3	.0	32	.15	194	140	32	321	7.2	5
242	6-25-63	300	52.5	16	.19	.01	6.0	2.7	3.9	1.4	0	36	4.0	2.1	.1	1.6	.00	56	26	0	75	7.4	5
264	5- 1-64	80	......	12	.04	.02	73	11	16	.0	0	198	61	15	.0	16	.01	302	227	65	508	7.7	5
265	2-27-61	700	......	26	.07	.03	60	6.2	14	1.3	0	154	67.0	7.5	.0	7.2	......	265	175	49	399	7.3	2
274	5-14-64	140	......	18	.09	.00	46	5.8	5.8	.2	0	142	8.4	5.5	.0	26	.02	186	139	23	305	7.7	3
301	5-13-64	186	......	28	.25	.01	90	12	15	.0	0	268	31	23	.0	29	.05	360	274	55	584	7.0	4
311	5-18-64	80	......	15	.04	.00	32	6.6	9.4	1.2	0	116	10	5.3	.0	21	.01	158	107	12	250	7.5	3
341	5-16-64	40	......	18	.04	.00	19	3.9	6.9	.2	0	74	10	3.2	.0	6.1	.03	104	64	3	165	6.9	3
342	5-23-63	17	53	12	.04	.00	20	12	15	4.0	0	18	37	18	.0	73	.18	200	100	85	317	6.0	3
374	3- 1-61	82	......	16	.12	.07	12	6.2	8.3	2.2	0	36	26	5.5	.0	15	......	109	56	26	166	6.2	1
392	5- 1-64	87	50.5	15	.13	.00	38	9.7	11	2.5	0	100	32	8.4	.0	39	.03	205	135	53	331	6.9	3
405	5-15-64	122	......	16	.04	.01	50	9.4	15	.0	0	123	49	17	.0	28	.02	245	164	63	402	7.7	3
442	5-24-63	156	......	16	.08	.00	56	8.4	4.5	.2	0	135	23	9.4	.0	38	.08	222	174	64	367	7.7	3
449	5- 4-64	110	54	13	.39	.24	45	13	8.0	.5	0	189	14	3.8	.0	15	.01	205	166	11	347	7.8	5
464	3-26-64	140	......	5.2	.03	.01	48.	12	2.6	.0	0	152	20	7.2	.0	29	.04	199	170	45	349	6.9	5
474	3-24-64	252	......	15	.05	.00	43	7.3	12	1.5	0	123	20	26	.0	9.2	.02	195	138	37	333	7.3	5
492	6 -6-62	100	......	5.9	.20	.03	56	8.1	15	5	0	60	39	32	.0	84	.18	270	173	124	449	6.4	3
b511	3- 1-61	96	......	20	.10	.00	23	7.1	10	2.3	0	78	13	10	.0	23	......	147	87	23	223	6.5	1

a Sanitary landfill 1,000 feet upslope.
b Gettysburg Formation

Table 6. Sample logs of wells in the New Oxford Formation, Lancaster County.

Well Ln-88

Owner: U.S. Geological Survey
Driller: C. H. Eichelberger
Static water-level: 20.5 feet below land surface, 6-24-63
Principal water-yielding zones: 96 and 163 feet
Samples collected and described by H. E. Johnston, U.S. Geological Survey

Description	Depth (feet)
Sand, very fine-grained, silty, yellowish-brown	0 — 10
Gravel, granule, dark-yellowish-brown; 6-inch boulder at 13 feet	10 — 15
Gravel, pebble, dark-yellowish-brown	15 — 20
Siltstone, slightly micaceous, grayish-red, soft	20 — 25
Siltstone, slightly micaceous, calcareous, reddish-brown, soft	25 — 37
Sandstone, very fine-grained, slightly micaceous, gray	37 — 45
Siltstone, slightly micaceous, calcareous, grayish-red	45 — 50
Siltstone, calcareous, dark-reddish-brown	50 — 62
Sandstone, very fine-grained, gray	62 — 64
Sandstone, very fine-grained, gray; some dark-gray siltstone	64 — 70
Sandstone, very fine-grained, micaceous, gray; muddy cuttings at 70 feet	70 — 75
Sandstone, fine-grained, quartzose, micaceous, gray	75 — 80
Sandstone, fine-grained, quartzose, micaceous, gray; slightly limonite stained	80 — 95
Sandstone, fine-grained, gray; some very fine-grained quartzose sandstone and black carbonaceous shale (water-yielding zone 1-foot thick at 96 feet)	95 — 103
Shale, calcareous, grayish-black	103 — 105
Siltstone, micaceous, grayish-red	105 — 107
Sandstone, fine-grained, gray	107 — 110
Sandstone, very fine-grained, quartzose, micaceous, gray	110 — 113
Limestone, dark-gray	113 — 114
Shale, grayish-red	114 — 115
Siltstone, micaceous, grayish-red; some very fine-grained gray sandstone	115 — 130
Sandstone, very fine-grained, quartzose, micaceous, gray, very hard	130 — 150
Sandstone, fine-grained, quartzose, gray; slightly limonite stained at 153 feet	150 — 155
Sandstone, fine-grained, slightly micaceous	155 — 160
Sandstone, fine- to medium-grained, quartzose, slightly micaceous with scattered coarse quartz grains, very light-gray	160 — 163
Sandstone, fine-grained, quartzose, very light-gray; interbedded gray siltstone (water-yielding zone 1-foot thick at 163 feet)	163 — 178
Siltstone, gray	178 — 185
Sandstone, very fine-grained, slightly micaceous, greenish-gray	185 — 199
Sandstone, fine-grained, quartzose, slightly micaceous, gray	199 — 215
Sandstone, medium-grained, quartzose, gray, with a few coarse quartz grains	215 — 220
Sandstone, fine- to medium-grained, quartzose, very light-gray	220 — 225
Sandstone, fine-grained, quartzose, greenish-gray	225 — 230
Sandstone, medium- to coarse-grained, quartzose	230 — 235
Siltstone, siliceous, slightly micaceous, greenish-gray	235 — 240

Table 6. Sample logs—Continued

Well Ln-88—Continued

Siltstone, grayish-red	240 — 248
Sandstone, very fine-grained, slightly micaceous, greenish-gray	248 — 268
Sandstone, fine-grained, quartzose, slightly micaceous, greenish-gray; some greenish-gray siliceous siltstone	268 — 295
Siltstone, slightly micaceous, grayish-red	295 — 305

Well Ln-265

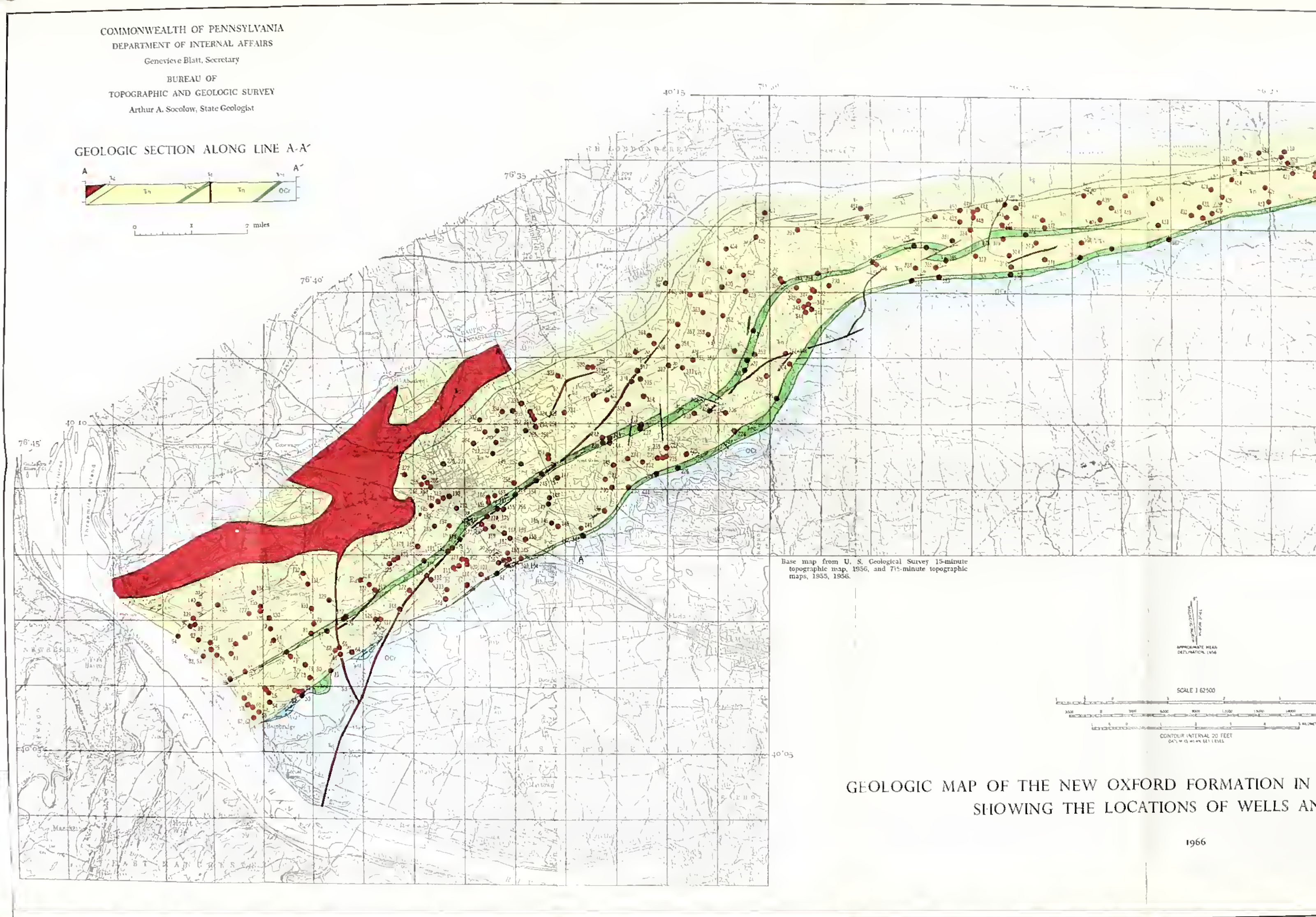
Owner: Elizabethtown Water Co.
Driller: Kohl Bros. (Harrisburg)
Static water level: 55 feet below land surface, 4-29-54
Principal water-yielding zones: One-third of the yield was obtained above 500 feet and two-thirds of the yield was obtained between 500 and 700 feet
Samples described by R. M. Foose and G. M. Cresswell, formerly of Franklin and Marshall College

Description	Depth (feet)
Arkose, fine- to medium grained, tan; abundant muscovite	1 — 25
Arkose, fine- to medium-grained, bluish-gray to greenish-gray; abundant muscovite	25 — 50
Siltstone, dark-red; abundant muscovite; arkose, fine- to medium-grained, gray, soft; arkose, fine-grained, buff gray; abundant mica	50 — 75
Arkose, medium-grained, greenish-gray, soft; some chlorite; arkose, fine- to medium-grained, tan; some muscovite	75 — 110
Arkose, fine- to medium-grained, gray; arkose, fine-grained, tan; abundant muscovite	110 — 120
Arkose, fine- to medium-grained, grayish-white; some chlorite; arkose, fine-grained, tan; abundant muscovite	120 — 130
Arkose, fine-grained, gray to dark-gray; abundant biotite; arkose, fine-grained, dark-red	130 — 150
Siltstone, red; siltstone, gray; arkose, fine-grained, greenish-gray	150 — 170
Arkose, fine- to medium-grained, greenish-gray; abundant mica	170 — 190
Arkose, fine- to medium-grained, dirty-white, micaceous	190 — 210
Sandstone, arkosic, fine- to medium-grained, quartzose, dirty-white to gray; abundant euhedral pyrite	210 — 230
Arkose, fine- to medium-grained, dirty-white, micaceous, abundant quartz; arkose, fine-grained, gray	230 — 240
Siltstone, dark-red; abundant mica; arkose, fine-grained, greenish-gray; abundant mica	240 — 250
Arkose, fine-grained, gray, soft	250 — 260
Sandstone, quartzose, and siltstone, bluish-green to dirty white, calcareous	260 — 270
Siltstone, dark-red; siltstone, gray	270 — 280
Sandstone, fine-grained, silty, red; sandstone, fine-grained, gray	280 — 290
Sandstone, fine-grained, grayish-green; siltstone, dark-red	290 — 300
Sandstone, fine-grained, light-buff, soft; some dark-red soft siltstone	300 — 320
Sandstone, fine-grained, grayish-green to dark-gray, somewhat calcareous, fairly hard	320 — 330

Table 6. Sample logs—Continued

Well Ln-265—Continued

Description	Depth (feet)
Sandstone, fine-grained, grayish-green to dark-gray, somewhat calcareous, fairly hard; siltstone, buff, soft; siltstone, dark-red	330 — 340
Sandstone, fine-grained, grayish-green to gray; siltstone, dark-red	340 — 350
Arkose, fine-grained, dirty-white to greenish-gray, somewhat calcareous, fairly hard	350 — 370
Sandstone, fine-grained, dirty-white, soft, somewhat calcareous; sandstone, fine-grained, grayish-green	370 — 380
Sandstone, arkosic, fine-grained, dirty-white	380 — 390
Sandstone, fine-grained, dirty-white to greenish-gray, slightly calcareous, fairly hard; siltstone, buff, soft	390 — 400
Sandstone, fine-grained, gray, calcareous, fairly hard	400 — 410
Siltstone, gray	410 — 420
Siltstone, gray; arkose, fine-grained, dirty-white to greenish-gray, calcareous	420 — 430
Siltstone, gray; arkose, fine-grained, dirty-white	430 — 440
Siltstone, gray; arkose, fine-grained, dirty-white, calcareous	440 — 450
Arkose, fine-grained, dirty-white, calcareous	450 — 460
Siltstone, gray, slightly calcareous; siltstone, dark-red; arkose, fine-grained, dirty-white, calcareous; shale, bluish-gray; some calcite	460 — 470
Siltstone, dark-red; siltstone, gray; arkose, fine-grained, dirty-white to greenish-gray, calcareous	470 — 480
Arkose, fine-grained, dirty-white to greenish-gray, slightly calcareous	480 — 490
Arkose, fine-grained, dirty-white to gray, calcareous; siltstone, dark-red	490 — 500
Siltstone and shale, dark-red	500 — 530
Sandstone, arkosic, fine-grained, grayish-green	530 — 580
Sandstone, quartzose, fine- to medium-grained, light-gray to white, slightly calcareous; some pyrite	580 — 600
Siltstone, dark-red	600 — 620
Sandstone, arkosic, fine-grained, greenish-white, calcareous, micaceous	620 — 630
Arkose, fine-grained, dirty-white, calcareous; some muscovite; arkose, fine-grained, grayish-green; some mica	630 — 640
Arkose, very fine-grained, dark-red, very calcareous; some mica	640 — 650
Arkose, very fine-grained, dark-red; arkose, fine-grained, gray, calcareous	650 — 660
Arkose, fine-grained, gray, calcareous; some muscovite	660 — 670
Arkose, fine-grained, greenish-gray, calcareous; abundant mica	670 — 705


COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist
GEOLOGIC SECTION ALONG LINE A-A′
A
A′
Tn
OCr
miles
Base map from U. S. Geological Survey 15-minute topographic map, 1956, and 7½-minute topographic maps, 1955, 1956.
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
GEOLOGIC MAP OF THE NEW OXFORD FORMATION IN
SHOWING THE LOCATIONS OF WELLS AN
1966

Geology by D. B. McLaughlin, 1964
Hydrology by H. E. Johnston

MAP OF THE NEW OXFORD FORMATION IN LANCASTER COUNTY, PA., SHOWING THE LOCATIONS OF WELLS AND SPRINGS

EXPLANATION

TRIASSIC

Upper Triassic

Diabase

Dark-gray, fine- to coarse-grained rock of basaltic composition. Intrusive into the New Oxford Formation and adjacent rocks as dikes and sills

NEWARK GROUP

Gettysburg Formation

Red to brown, fine- to coarse-grained sandstone with red shale interbeds, interbedded shale and limestone conglomerate; and quartz pebble conglomerate

New Oxford Formation

Light-gray to buff, fine- to coarse-grained subarkosic sandstone interbedded with red, fine-grained sandstone, siltstone, and shale; quartz pebble conglomerate, and limestone conglomerate. In general, poorly to moderately permeable. Yields of 100 to 300 gallons per minute are obtainable from some deep wells

UNCONFORMITY

CAMBRIAN AND ORDOVICIAN

OCr

Sedimentary Rocks, Undivided

Includes limestone, dolomite, shale, and phyllite

SYMBOLS

Contact

Fault
U, upthrown side, D, downthrown side

Strike and dip of bedding

A——A'
Line of cross section

Well

Spring

Numbers by symbols refer to listings in tables.